BIOLOGY FOR HIGH SCHOOLS

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BIOLOGY

FOR

HIGH SCHOOLS

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ALLYN AND BACON

BOSTON NEW YORK CHICAGO
ATLANTA SAN FRANCISCO

Norwood Press
J. S. Cushing Co. — Berwick & Smith Co.
Norwood, Mass., U.S.A.

To

Our Alma Mater, Syracuse University

In Recognition of the Completion of
Fifty Years of Service to Education

PREFACE

Biology for High Schools was written to show the close relationship of the science of biology to human life. The treatment gives a broad survey of the life of plants and animals, including man.

Specifically the book aims to do six things:

(1) To teach the pupil to see accurately what he looks at and describe exactly what he sees.

(2) To teach him to think clearly and to base his conclusions upon his facts.

(3) To broaden his knowledge of his own body through the study of the structure and functions of other animals and of plants.

(4) To show him by the adaptations of plants and animals how he can adapt himself to the varying conditions of life.

(5) To make him a good citizen through his knowledge of good food, good health, and good living conditions.

(6) To teach him how biology has helped human progress and welfare.

Biology for High Schools gives due attention to laboratory and notebook work. It makes the most of the pupil's interest in recording personal discoveries about living things, and guides him by easy steps from simple pencil sketches to more elaborate pen drawings.

A special feature of the book is the thorough treatment of the practical side of biology, with reference to the prevention of disease, particularly in its epidemic forms, through sanitation and right living.

The last chapter is on *Biology and Human Progress*, and

treats such varied subjects as the new discoveries which have made for progress by improving human environment; quarantine regulations for the protection of domestic fruits from foreign destructive insects; the functions of the United States Department of Agriculture; and the principles of variation and heredity as they affect both the cultivation of the soil and human life.

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May, 1920.

ACKNOWLEDGMENT OF ILLUSTRATIONS

Guy A. Bailey, Bird and Mammal Photographs (in nature).
W. L. Bray, Syracuse University, 342, 347, 348.
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INTRODUCTION

DEFINITION OF COMMON BIOLOGICAL TERMS

Adaptation. — Have you ever seen a squirrel run up a tree, hurry along the branches, then jump to another tree and disappear in the foliage? Did it occur to you as you watched him that he was adapted to the mode of life that he was leading? His toes are provided with sharp, curved nails that make it easy for him to hold fast to the rough bark of the tree; and, when he jumps from branch to branch, his tail acts as a parachute, so that his front feet alight first.

FIGURE 1.

Notice how the squirrel holds the nut with his front feet. What use is made of his hind feet at this time? Are his front feet being used as hands or feet? Compare the tail of the squirrel with the tail of a mouse (Figure 120). Of what use to a squirrel is a big bushy tail? Would such a tail be useful to a mouse? Would it be a detriment? Why?

Did you ever notice how he holds the nut in his front feet and how he uses his cutting teeth to get the kernel? The feet thus used as hands and the teeth used for cutting are adaptive features. If a squirrel has more food than he can eat at once, he takes the nuts and buries them in the earth. In doing this he uses his front feet for digging a hole in the ground

while holding the nut in his mouth. After the hole is dug, he pushes the nut into the bottom of the hole with his teeth and pulls the earth over the nut with his feet. These are additional uses of his feet and teeth due to their adaptations.

FIGURE 2.

Notice how the thumb and first two fingers hold the pen securely. The flat wrist gives a good sliding surface and the muscles are so controlled that the letters are uniform in size and shape. The nails of the fingers are adaptations and can be used to pick up small objects. The numerous joints in the fingers make the hand more serviceable. How many adaptative features of the hand can you think of?

Did you ever think of your hand as an adaptation? When you use a fountain pen in what ways is the hand adapted to the use of this instrument? First, you take it from your pocket. Then you take the cap from the pen with

one hand, while you hold it with the other. You place the cap on the top of the pen, the fingers exerting just the right pressure in removing it and forcing it on the pen. Then you take the pen in your right hand and start to write. The pen point is moved in the proper direction to make letters, forming accurate loops and curves because the hand has been trained to make these lines as you wish. It has become especially adapted to do this work.

You write a page and take a blotter and press it upon the freshly written word. The hand is just the thing to use for this work. Suppose you make a mistake and wish to erase it. An ink eraser which you hold with your fingers you move back and forth with the proper force and without tearing the paper. Suggest other ways in which the hand is adapted to the work of writing. Think of the hand of a violinist as it rapidly moves over the strings, pressing at the right place at the right time. This is the work of a wonderfully adapted hand. The human hand is the best example of varied adaptations that we know of.

FIGURE 3.

The different "seeds" in this picture are all distributed by wind. What are the various devices shown on these seeds which enables the wind to carry them?

Did you ever think of the seeds of the maple tree that grow large winglike vanes on the side? The wind carries these seeds away from the parent tree and thus they have a better chance to grow. The dandelion has downy tufts on a stem that grows up from the seed coat and carries the seed miles away from the place where the parent plant grew.

The cocoanut has a buoyant husk that causes it to float in the currents of the ocean perhaps a hundred miles away till the waves carry it up on the shore, where it grows into a cocoanut tree. Some plants, like the wild geranium, hold the seed by a spring that throws the seed several feet, if it is touched. These are all adaptations that plants employ in making their kind grow.

Animals and plants have come to occupy places in various parts of the earth because they have become fitted or adapted to the varying conditions. The main adaptations that have to do with the individual are: (1) those that assist in food getting, such as the cutting teeth of the squirrel or the sharp curved beak of the hawk or eagle (see Figure 99); (2) those that aid in self-protection, such as the rapid running of the fox or the color of a moth (see Figure 31); and (3) those that have to do with their surroundings, such as the fish, which is provided with fins for use in moving through the water, or the bird that has wings to fly through the air.

Then there are adaptations that have to do with rivalry and the welfare of the young. Among the males of sea lions there is great rivalry which ends in the survival of the fiercest and strongest and death to the smallest and weakest. These contests among the males assure the young of sturdy parentage. Tusks, horns, and biting teeth are some of the adaptations. Certain fish, most birds, and some insects build nests where the young are cared for and given added protection. The building of nests, together with the behavior of the adults during this time, are adaptations for the care of the young.

If we inquire more critically into the way plants and animals live, we shall see that they have in common other features besides adaptations. These are sometimes described as the *fundamental functions* of all living things. We shall need to know these before beginning the study of animals and plants. These fundamental functions are motion,

nutrition, respiration, excretion, sensation (irritability), and reproduction.

Motion. — All animals can move from place to place or move parts of their bodies. The higher animals move with ease as a result of highly developed muscular and nervous systems. The lower animals are more limited in their movements. The simpler plants move about in the water and at least the leaves of many of the higher plants move toward the sunlight, and the hop-vine and morning-glory not only grow but move in a certain direction around a pole.

Nutrition. — This function includes the preparation of food so that the animal or plant may have it in the form of a solution. This is digestion. Next, the food must be taken into the veins of the animal or plant. This is absorption. Then the food must be moved to all parts of the animal or plant. This is circulation. And, lastly, each part of the animal or plant must take from the blood or sap the food that it needs. This is assimilation. Nutrition is the term under which are described the changes through which food passes from the time it enters into solution until it becomes a part of the living body of an animal or plant.

Respiration. — All animals and plants require energy in order to live. Part of this energy comes from the food and part from the oxygen used in the process known as respiration. As a result of respiration the needed energy is obtained and a by-product, carbon dioxide, is formed. Respiration, which takes place in every living cell, should not be confused with breathing, the process by which the higher animals get air in and out of their lungs.

Excretion. — The formation of by-products in the bodies of animals and plants and their removal is called excretion. The skin, lungs, and kidneys in animals remove excretions. In plants they are not always removed but are isolated where they can do no harm.

Sensation (Irritability). — Animals are sensitive to heat, to pain, to light, and to other outside influences (stimuli). Plants, too, respond to light and other stimuli. The response of animals and plants to stimuli is called *sensation* or *irritability*. It is an important life process or function, for it enables them to make the most of their location. Because of this function animals and plants are able to adapt themselves to their surroundings.

The foregoing life processes have to do with the life of the animal or the plant itself. There is another life process that is important in keeping alive the races of animals and plants, namely, *reproduction*.

Reproduction. — All animals and plants produce young or become extinct. The old die and the young carry on the work of the race. The number of animals and plants is increased on the earth by means of the life process known as reproduction.

These six fundamental functions or life processes are to be found in all animals and plants. In some cases it is difficult to study them, for they are hidden or masked by other processes, or the animal or plant may be so small that we cannot easily make them out.

Biology is the science that deals with the lives of animals and plants. It seeks to understand how they are adapted to the kind of life they lead and how they carry on their life processes by means of various structures.

The Parts of Bodies. — These life processes tell us what the parts of bodies do, but they tell us nothing about these parts themselves. There are five words which are used in biology to describe these parts. They are: *cell*, *tissue*, *organ*, *organ system*, and *organism*.

1. *The Cell.* — When the biologist takes apart the plant or animal he finds that he can separate the parts until he comes to a unit so small that a microscope is necessary to see it. These microscopic parts are called *cells* and are alike

in the following respects: each one has a clear outer portion called the *cell wall* which incloses a mass of substance known as *protoplasm* (prō′tō-plaz'm: Greek, *protos*, first; *plasma*, form). The protoplasm is made up of a substance called *cytoplasm* (sī′tō-plaz'm: Greek, *kytos*, hollow place; *plasma*, form), in which is held a saclike body, the *nucleus* (nū′klē-us: Latin, *nucleus*, kernel, nut). The nucleus usually contains one or more separate bodies called *nucleoli* (nū klē′ō-lī). A cell is therefore defined as a *mass of protoplasm composed of cytoplasm and nucleus* (Figure 4).

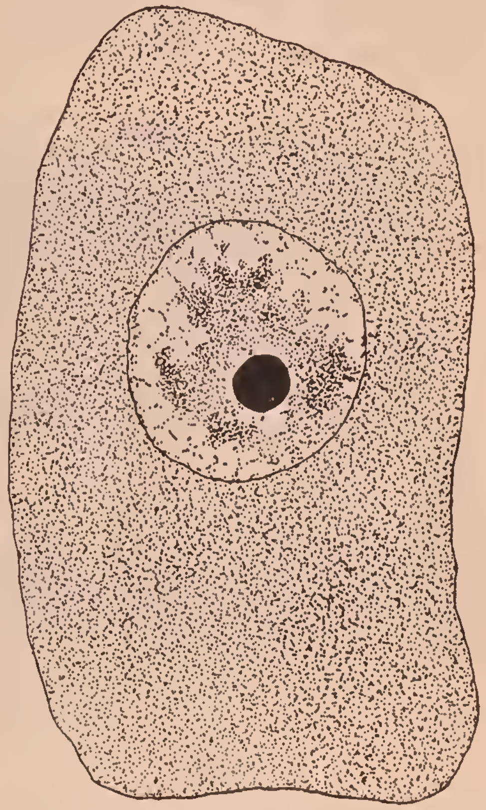


FIGURE 4. — A TYPICAL ANIMAL CELL.

Identify the different parts from the description in the text. Compare the parts and shape of this cell with the cells shown in Figure 5. What conclusions can you draw?

2. *Tissues.* — The cells are of many shapes and sizes, and in the bodies of all but microscopic plants and animals they are united to help the plant or animal carry on its life processes. This union of cells to do a certain work is called a *tissue*, and the usual definition is: *a tissue is a group of similar cells that do a similar work* (Figure 5).

3. *Organs.* — In all the higher animals the tissues are united into skin, arms, stomach, and so on, or in plants into leaf, branch, etc. Such structures are called *organs; an organ is defined as a group of tissues that do a given work in the animal or plant.*

4. *The Organ System.* — When different organs combine to carry on such a general life process as digestion, all the parts that assist in this process are described as an *organ system*, as the system of digestive organs.

5. *Organism.* — Every living thing is an organism. It may be so small that the microscope is needed to see it. Nevertheless it is an organism. If it is a large tree, like a giant redwood, it is an organism. Elephants, horses, and men are organisms.

These five expressions, *cell, tissue, organ, organ system,* and *organism* describe the parts of plants and animals which carry on the six *life processes* referred to above. We shall read more about them as our study of biology progresses.

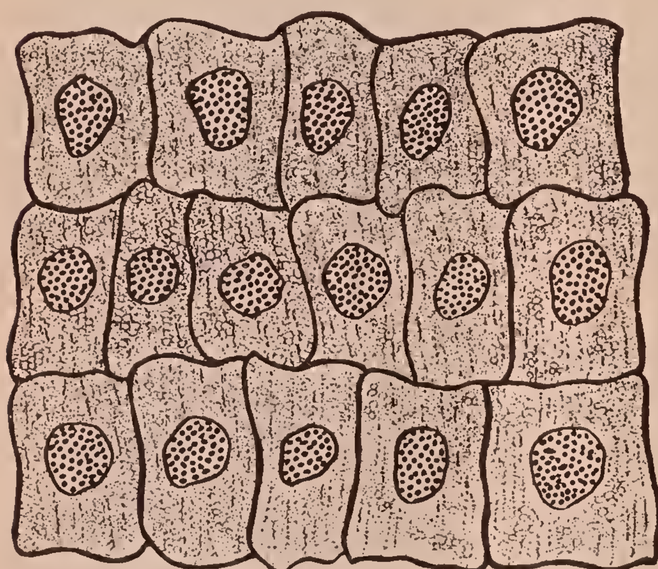


Figure 5. — Similar Cells United to Form a Tissue.

Compare these cells with the one shown in Figure 4.

Classification of Living Things. — Our study of biology cannot progress far before we see the need of classifying animals and plants. Animals are generally grouped in two divisions: *invertebrates* (animals without backbone) and *vertebrates* (animals with backbone). Plants are also divided into two groups: *cryptogams* (flowerless and seedless plants) and *phanerogams* (flowering or seed-bearing plants). Below is given a detailed reference table of these classifications.

I. Invertebrates. Animals without a backbone.
   1. Protozoa. 8000 different kinds, as, amœba, paramœcium.
   2. Porifera. Sponges, 2500 different kinds. Examples, the bath sponge and grantia.
   3. Cœlenterata. Hydra, corals, and jellyfish. 4500 different kinds.
   4. Echinodermata. Starfishes and sea urchins. 4000 different kinds.

5. Worms and wormlike animals. Examples, flat worms, tape worms, earthworms. 11,000 different kinds.
6. Mollusca. The clams and snails. 61,000 different kinds.
7. Arthropoda. Crabs and insects. 400,000 different kinds.
   a. Crustacea. Examples, crayfish and crabs. 10,000 different kinds.
   b. Insecta. Examples, grasshopper, flies, butterflies, bees. 390,000 different kinds.

II. VERTEBRATES. Animals with a backbone.
1. Pisces. Examples, trout, perch, bass, cod. 13,000 different kinds.
2. Amphibia. Examples, frog, salamander. 14,000 different kinds.
3. Reptilia. Examples, snakes, turtles, alligators. 35,000 different kinds.
4. Aves. Examples, sparrow, eagle, hawk, crow. 13,000 different kinds.
5. Mammalia. Examples, horse, cow, sheep, monkey, man. 35,000 different kinds.

The plants, like the animals, are arranged in general groups which, beginning with the simplest, are as follows:

I. CRYPTOGAMS. Flowerless or seedless plants.
1. Thallophytes.
   a. Algæ.
   b. Fungi. 67,000 different kinds. Examples, bacteria, molds, puff-balls, toad-stools.
2. Bryophytes.
   a. Liverworts. 4000 different kinds.
   b. Mosses. 12,600 different kinds.
3. Pteridophytes. 4500 different kinds of ferns.

II. PHANEROGAMS. Flowering or seed-bearing plants.
1. Gymnosperms. Examples, pine, spruce. 540 different kinds.
2. Angiosperms. Flowering plants proper.
   a. Monocotyledons. Example, corn. 23,700 different kinds.
   b. Dicotyledons. Example, bean. 108,800 different kinds.

Scientific Terms. — Scientists in America, France, Germany, Russia, and elsewhere are continually studying different plants and animals. For their convenience the Latin names are usually adopted in advanced scientific

works. Thus the *English* or *house sparrow* is called *Passer domesticus*, and the *American elm*, *Ulmus americana*, so that scientists of different countries may always use the same term. But in this book we shall use the common American names of the plants and animals studied.

Scientific terms include also names frequently referred to in science books like this Biology, such as physical and chemical change, environment, and energy.

Physical and Chemical Change. — If a solid piece of ice is melted, it becomes liquid water. If the liquid water is boiled, it becomes gas (steam or vapor). If the steam is condensed, it becomes water, which in turn may again be frozen into ice. Any change in a substance which does not alter the material of which it is composed is called a *physical change.*

On the other hand, when oxygen unites with wood, the wood may burn, giving off heat and smoke, and ash remains. But this ash cannot be united with heat and smoke to form the original wood. Such a change as is seen in the burning of wood is called a *chemical change.*

Organic and Inorganic Matter. — It is customary to separate chemical compounds which are made in living things from those which are made outside the bodies of plants and animals. All matter such as wood, sugar, and meat, which is made in living things, is called *organic* matter. All matter, like stones and water, which is made outside of living things, is called *inorganic.*

Environment. — Plants and animals have accustomed themselves to live in different parts of the world. Their behavior and habits under these varying conditions form a most interesting part of the study of biology. The surroundings of plants and animals, that is, the different conditions, the air, water, climate, and soil in which they live, are called their *environment.*

Energy. — To carry on the fundamental processes of

plants and animals, energy is needed. Energy is defined as the power to do work. It is produced in animals chiefly by the action of oxygen on carbon compounds. Oxidation is the source of the larger amount of animal energy. The amount of energy is in proportion to the amount of oxidation. Heat is a form of energy.

Conservation of Energy. — The source of all energy on the earth is the sun. The heat and light of the sun make it possible for plants to grow. Plants store up energy in the form of starch, wood, and sugar. Animals eat these stores of energy and convert them into the energy of heat and motion.

Coal is stored energy from the plants of ages ago. The coal is placed in furnaces and burned. This furnishes energy in the form of heat. The heat produces steam, which is converted into energy in the form of motion. This motion may be converted into energy in the form of electricity. Electricity may be converted into light or motion.

We may sum up in this way. The light of the sun made plants grow which were transformed into coal. The coal was burned under the boiler, making the steam which ran the engine. The engine turned the dynamo and produced electricity. This electricity was passed through a small wire in an electric bulb and furnished light. The light of ages ago is again made into light by this long process. It has traveled in a circle, so to speak. Energy may be converted into various forms. Electricity may be changed to heat, as in the electric flat-iron; into light, as in the electric bulb; or into motion, as in the trolley car. One form may be converted or changed into other forms of energy. If energy is used in one form, it will appear in some other form. Energy cannot be created or destroyed.

Elements and Compounds. — The bodies of plants and animals as well as the earth and air are composed of a great variety of compounds and elements. The starch found in

wheat, potatoes, and corn is a compound of three elements; namely, hydrogen, carbon, and oxygen. Elements cannot be divided into simpler substances. Compounds are made up of elements in chemical combination. There are thousands of kinds of compounds. Calcium carbonate is a compound that makes up a large part of limestone rock. Water is a compound made of hydrogen and oxygen. Wood is made up of compounds, one of which is cellulose which is very similar to starch. There are fewer than ninety elements known at present, but new ones are being discovered from time to time.

Oxygen, carbon, nitrogen, hydrogen, calcium, and iron are the elements that make up the principal parts of plant structures and animal bodies.

Oxygen. — This is a gas. It is uncombined in the air, making up one fifth of its volume. It readily combines with many other elements. The darkening of unpainted barns and fences is an example of the union of oxygen with other elements. Opening the draft of a stove or furnace allows more oxygen to enter and increases the rate of the combination of oxygen with the coal or wood. This raises the temperature. The process of oxygen combining with other elements, either slowly as in the rusting of iron or rapidly as in the furnace, is called oxidation. Slow oxidation, like the rusting of iron, shows little heat at any one time, while rapid oxidation produces a greater amount of heat in a given time. The amount of heat depends on the rapidity of oxidation.

Oxygen is the most important element in the air. Plants and animals must use it to live. Respiration has been spoken of as a fundamental life process. Without oxygen there could be no respiration and consequently no plant and animal life as we know it.

Carbon. — This element, mixed with oxygen, is the most important to plant and animal life. It combines with

hydrogen and oxygen to form sugar, starch, fat, and wood. Charcoal is a form of carbon. It is made by burning wood with a small amount of oxygen. Coal is almost wholly carbon, while the diamond is carbon in the form of a crystal.

Nitrogen. — This element is an inactive gas and it does not readily combine with other elements. It dilutes the oxygen of the air, making it less active. Nitrogen comprises four fifths of the volume of the air. It is an important plant and animal food. Nitrates are compounds of nitrogen, oxygen, and some other elements. Potassium nitrate is a compound of nitrogen, oxygen, and potassium. Sodium nitrate is a compound of nitrogen, oxygen, and sodium. Such nitrates are the forms in which nitrogen can be used as plant food. Plants are unable to use the nitrogen of the air as a food directly. Proteins are animal and plant products that contain nitrogen. Proteins are necessary food for animals, and animals are dependent on plants to furnish these substances. See pages 278–280.

There are other elements that are needed in small amounts by animals, such as calcium, phosphorus, sulphur, potassium, and iron. The human body is made up of:

oxygen	72	parts	phosphorus	1.15	parts
carbon	13.5	"	sulphur	.147	"
hydrogen	9.1	"	potassium	.026	"
nitrogen	2.5	"	iron	.01	"
calcium	1.3	"			

Nutrients. — The elements above, while forming the body structure, are not taken directly as food. The foods we commonly use have these elements in combination with other materials. The foods that contain the proper elements are spoken of as nutrients. These nutrients are starches, sugars, proteins, edible fats, and mineral matter.

Starch is a nutrient that occurs in many of our foods. Potatoes, corn, wheat, rye, rice, and most of the vegetable

foods contain large amounts of starch. Starch is easily changed to glucose by the digestive fluids. It furnishes some of the energy of heat and motion for the body.

Glucose. — Glucose is a nutrient that occurs in grapes and in most other fruits. It is slightly different in composition from cane sugar or beet sugar. Starch is always changed into glucose by the digestive fluids and never into cane sugar. The food value of both glucose and cane sugar is high. They are used by the body to furnish the energy of heat and motion.

Enzymes. — In the preceding paragraph it was said that the digestive fluids change starch into glucose. For many years it was not known what substance in the digestive fluid causes it to do this work. Now it is known that certain substances called enzymes are the real active agents in digestion. The enzyme that changes starch to glucose is called diastase. Pepsin is an enzyme that digests protein. There are many other enzymes. An enzyme is not changed by digestion, so that a very small amount of it digests a large amount of food.

Proteins are nutrients that are found in great variety in our food. The proteins differ from starch and sugar in having nitrogen in combination with other elements. The characteristic element of protein is nitrogen. Each kind of protein has its own name. The protein in wheat is *gluten;* in beans it is *legumin.* *Casein* is the protein in milk and *myosin* is the protein in meat. The proteins are necessary in building and repairing the cells of animal bodies. If more proteins are eaten than necessary for this work, the surplus may be oxidized to furnish the energy of heat and motion or stored as fat.

Edible Fats. — The term *edible fats* is used to include both fats and oil. These nutrients are almost wholly energy producers. They are used chiefly to produce heat. As we go north or south from the equator, we find the native people

adding ever greater amounts of fats to their diet, until we come to the Esquimaux, who eat large quantities of pure fat with relish. Large amounts of fat are necessary to keep the body warm in the very cold zones.

Mineral Foods. — Salt is a most important mineral food. It is so frequently used to give a flavor to our food that we do not realize its real importance. A well-nourished animal or plant must have it to a certain amount. Deer travel long distances for it. Most of the other minerals are found in ordinary food so that it is not necessary to use them as we do salt.

Osmosis. — Foods in the form of solutions must be taken into the walls of the stomach and intestines and through the cell walls of plants. These structures have no pores that we are able to see with a microscope and yet the solutions pass through. *This passing of food and water through animal and plant cells is osmosis.* The term *osmosis* is also used when a gas, such as oxygen, passes through the skin or lungs into the blood. From time to time further explanations of this very complex process will be made. A simple device for illustrating osmosis is described in *Science*, Dec. 12, 1919, page 542, by Elbert C. Cole.

BIOLOGY FOR HIGH SCHOOLS

PART I

ANIMAL BIOLOGY

CHAPTER I

THE GRASSHOPPER, AN INTRODUCTION TO THE STUDY OF INSECTS

1. Variety of Animal Life. — There are more than six hundred thousand kinds of animals in the world. Of this large number nearly four hundred thousand kinds are insects. Insects are so widely distributed, have such a great variety of form and color, and are so numerous that the age in which man lives is sometimes called the age of insects. While insects do not have any representatives that are large, compared with dogs or horses, they make up in number what they lack in size.

Man's greatest competitor for the domination of the earth has been not the lions, rattlesnakes, or other large enemies, but the hosts of small animals of which the insects form the largest class. The building of the Panama Canal was as much a triumph over the disease-carrying mosquito as it was an engineering feat. Even to-day, many parts of the earth are uninhabitable because of mosquitoes.

The potato beetle, the chinchbug, the scale insects, the codling moth, the gypsy moth, the grasshopper, the army worm, and many others are taking a heavy toll each year from the world's food crop. The activities of these insects make food prices higher and it is in the interest of food con-

servation that more people should be aware of the common facts about insects. To do this it is necessary to get an idea of how they grow, how they get their food, what they eat, where their eggs are laid, how they reproduce, and how they may be controlled.

If a person studies rather closely the life history, structure, and activities of one insect, he has a fairly good idea of the great class of insects, for they are all much alike in many ways. Insects in some ways are like the higher animals, such as the fish, bird, dog, and man. All must have food, all must get oxygen, all have some way of self-protection, all reproduce, and all sooner or later die of accident, disease, or old age. Certain insects live as adults but a few hours, while elephants may live a hundred years or more. But all die in time and the young must come to take the places of the old if their particular race is not to become extinct.

All insects will be found doing something. Some are flying from flower to flower, and you can watch to see what they are doing; others are busy on the leaves or the stems, and a few minutes of observation will show you whether they are friends or foes of the plant upon which you find them. The most interesting way to study insects is to watch them in their home life, but when this cannot be done, they can be well studied in the laboratory. Even in the city a surprisingly large number of kinds of insects can be collected by a class and brought alive to the laboratory.

2. The Grasshopper. — The study of animals begins in this book with the grasshopper. When during the late summer we walk into the fields or along paths lined with grass, we are often surprised at the number of grasshoppers which jump away as we approach. They are of various sizes and kinds. Some are small and without wings, while others have small but well-formed wings. The difference in the wings and in the shape of the body tells us that there are various kinds of grasshoppers.

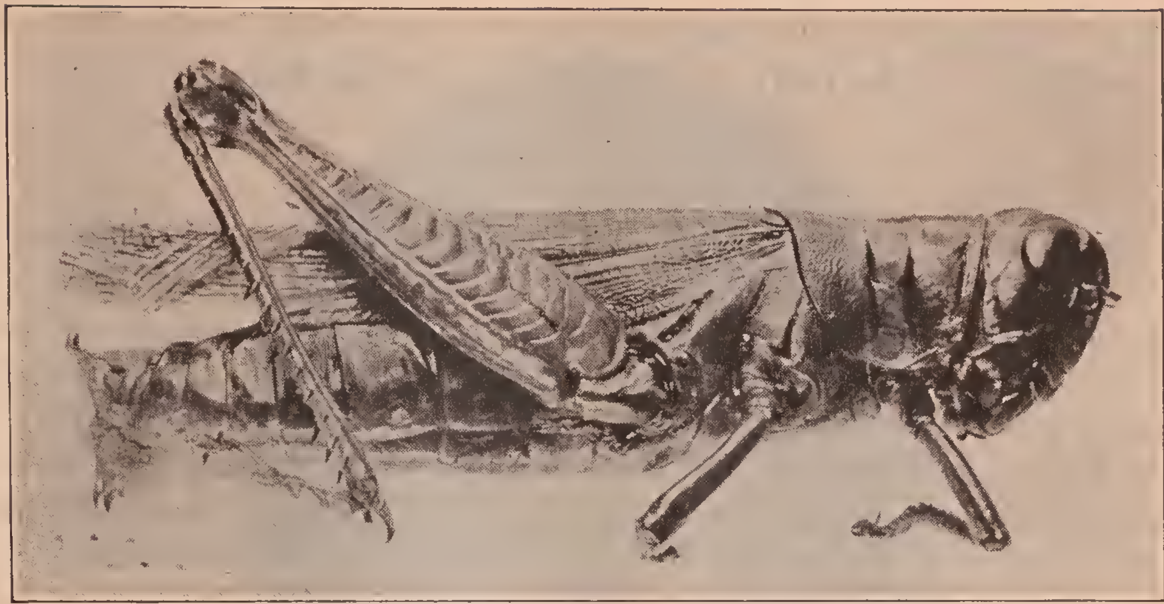


FIGURE 6. — FEMALE GRASSHOPPER.

Notice the position and shape of the modified legs at the end of the abdomen.

FIELD STUDY

Study living insects. Collect insects, such as grasshoppers, crickets, beetles, bees, wasps, flies, moths, butterflies, etc. Place some under tumblers and complete your report as follows:

	Where Found	Number of Legs	Number of Wings	Size of Wings	Size of Third Leg	Mouth Parts			
						Strong	Weak	Separate	Fused
House fly .	On food in the home	6	2	Small					
Grasshopper	On grass in the field	6	4	Medium					
Moth . .	On flowers in the park	6	4	Large					

3. Life Processes of the Grasshopper. — The young grasshopper must escape being eaten, must find food, must have oxygen to breathe, must be able to rid the body of waste substances, must be able to see, feel, and taste, must develop into an adult, and must do its part in providing for another generation of grasshoppers. If the grasshopper fails in any one of the first three of these necessities, it is unable to live,

and consequently the last and most important work, that of providing for the next generation, is not possible.

LABORATORY STUDY

Examine a live grasshopper. What are its means of locomotion? Compare its jump with its length. If in the same proportion, how far could a man six feet tall jump? How does the grasshopper obtain food? What protection from enemies does it gain from its color? Notice the division of the body into three regions: *head, thorax* (thō'răks), which has wings and legs, and *abdomen* (ăb-dō'mĕn). How large is the head compared with the thorax and abdomen? The body is covered with a skin-like substance, known as *chitin*. This is called the skeleton of the grasshopper and because it is on the outside of the body it is termed an *exoskeleton*. How does it protect the grasshopper? When the living grasshopper is held between the thumb and finger, it "spits molasses." This is the partially digested food from its crop.

4. Protection. — When we look closely at the grasshopper, we find that it is provided with many adaptations which prevent its being caught and eaten. The

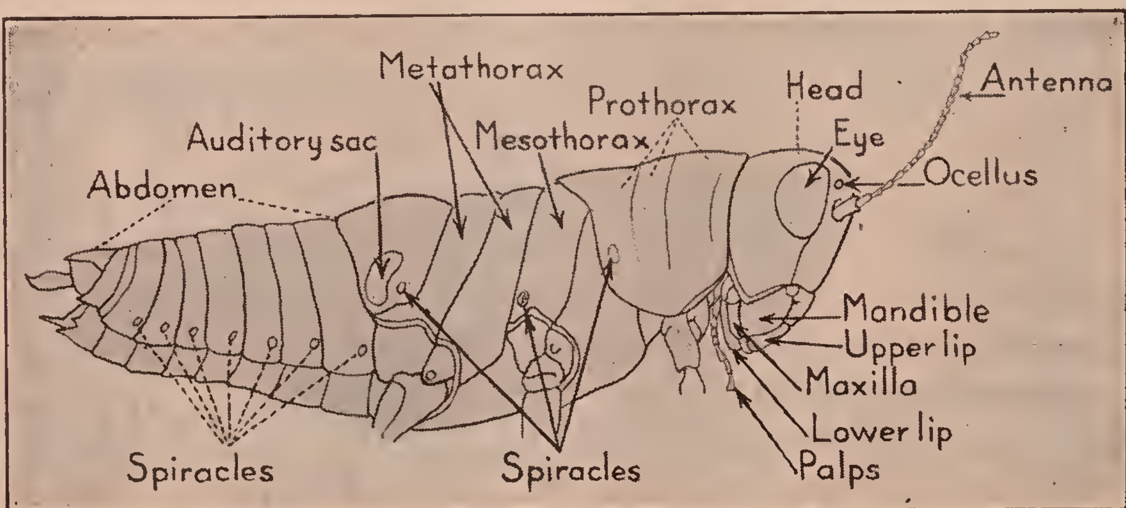
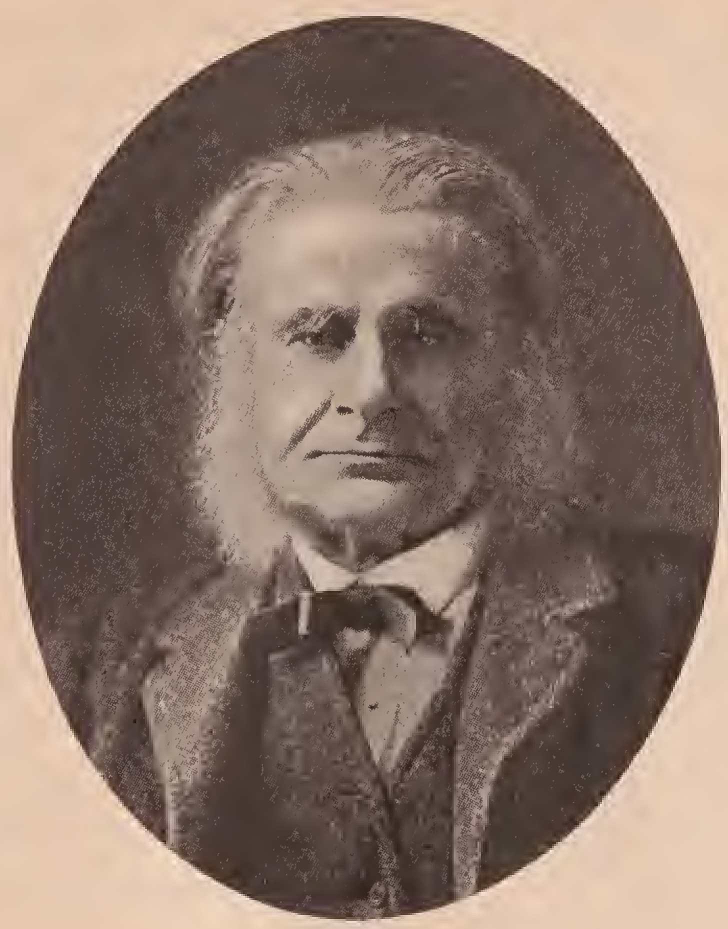


FIGURE 7. — DIAGRAM.

A drawing to show the more important parts of the grasshopper, all of which can easily be seen without the aid of special instruments.

most important of these are its color and markings. When a grasshopper jumps into the grass and remains quiet, its color so closely resembles the grass and the sticks that many of its enemies overlook it. This is an example of what is



Thomas Henry Huxley (1825–1895) was the father of the modern method of studying biology. Up to 1850 information about plants and animals was imparted only by lectures. Huxley found that science of his day contained many errors due to lack of first hand information on the part of the writers. He corrected many of these errors by personal study of plants and animals, and devoted years to developing methods of laboratory study which enabled the student to gain his information directly. To-day these methods are accepted wherever the subject of biology is studied. This great English biologist made many important discoveries and was awarded numerous honors by his countrymen. Huxley showed great skill in putting the conclusions of science into simple language.

called *protective coloration.* The grasshopper is further protected by a pair of large eyes and by simple ears, which are located on the side of the body. By means of these sense organs, it becomes aware of the presence of enemies. The quickness of grasshoppers in jumping also helps them to escape being eaten.

5. **Food-Getting.** — The grasshopper has little difficulty in finding its food. It eats leaves, and particularly the leaves of grass. It does not need a keen sense of smell, as does the bee, which must search for flowers. However, the grasshopper has special smelling organs located in its antennæ (ăn-tĕn′ē), those long feelers which grow out from the head like soft horns.

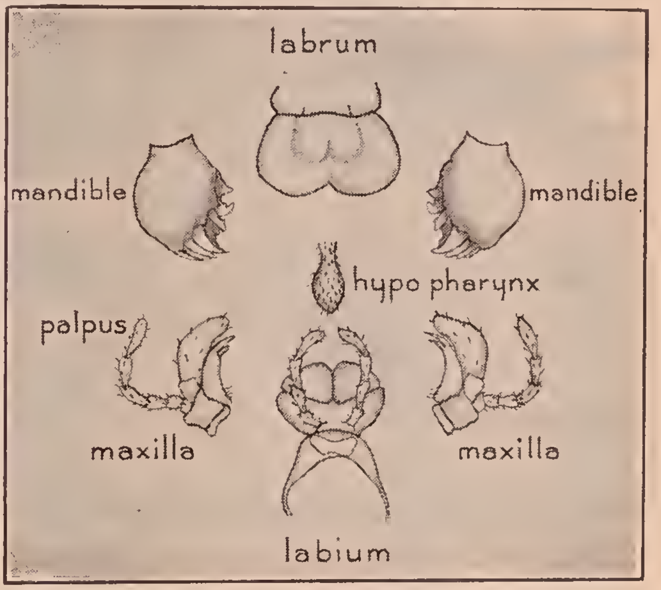


Figure 8.—The Lips and Teeth of the Grasshopper.

These show special adaptations which explain their peculiar shape and position. See if you can find out how each part is used when the grasshopper is eating.

The mouth parts which cut and chew the food consist of an upper lip and two teeth (mandibles, măn′dĭ-b'ls). The teeth are moved by powerful muscles which nearly fill the head. These mandibles work from side to side, instead of up and down as our teeth do. They are so effective that sometimes when grasshoppers become numerous they strip the grass of all its leaves, and even destroy growing fields of grain.

6. **Respiration.** — All animals have some way of getting oxygen to every portion of their bodies and of getting rid of carbon dioxide. The grasshopper has no lungs such as ours, nor does it breathe through its mouth. On each side

of the abdomen are eight regularly arranged, small openings, spiracles (spĭr′a-k’ls), which lead into branching tubes, tracheæ (trā′kē-ē). There are also two spiracles on the mesothorax. The branching tracheæ are kept open by means of skeleton-like rings so that the pressure of the muscles and other organs cannot flatten or close them. The tracheæ continue to branch until the subdivisions are so small that they can be seen only by aid of the microscope. These fine branches extend to the minute cells of which the body of the grasshopper is composed. Here the oxygen passes to the living protoplasm of the cells and carbon dioxide is given off to the air which is in these breathing tubes. This use of the oxygen by the protoplasm and the giving off of the carbon dioxide is *respiration*. (See Respiration, page 5.)

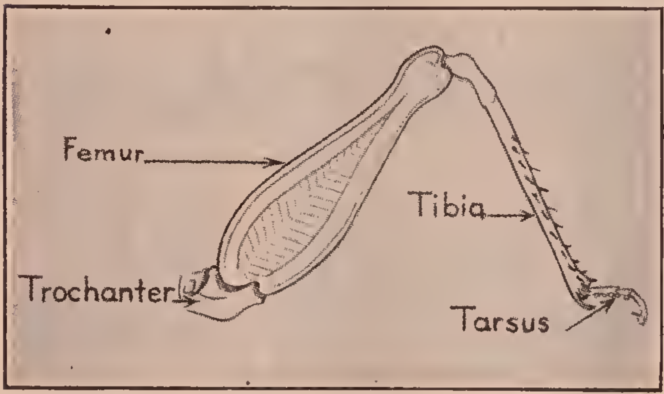


FIGURE 9. — THE JUMPING LEG OF THE GRASSHOPPER.

Why is the femur so much larger in this leg than in the one just in front of it?

7. Body Regions. — The grasshopper has three body regions: the head, the thorax, and the abdomen. Each of these regions is adapted to particular kinds of work. The head structures are adapted to food-getting, seeing, and feeling. The thorax has appendages for locomotion: walking, jumping, and flying. The abdomen is adapted to breathing, hearing, and reproduction.

The Head. — On the front of the head are three simple eyes and on the sides of the head two compound eyes. Near the simple eyes are two antennæ for feeling. The mouth has several special parts for food getting. (See Figure 8, page 21.) These parts are an upper lip (labrum), and a lower lip (labium) for moving the food into the mouth. Inside

the mouth is a pair of mandibles for cutting food and a pair of maxillæ with palps for carrying the food. The hypopharynx, a sort of tongue, is useful in handling the food.

The Thorax. — This is the second body region and it is composed of three parts. The prothorax, separate from the rest of the thorax, is provided with the first pair of legs. The

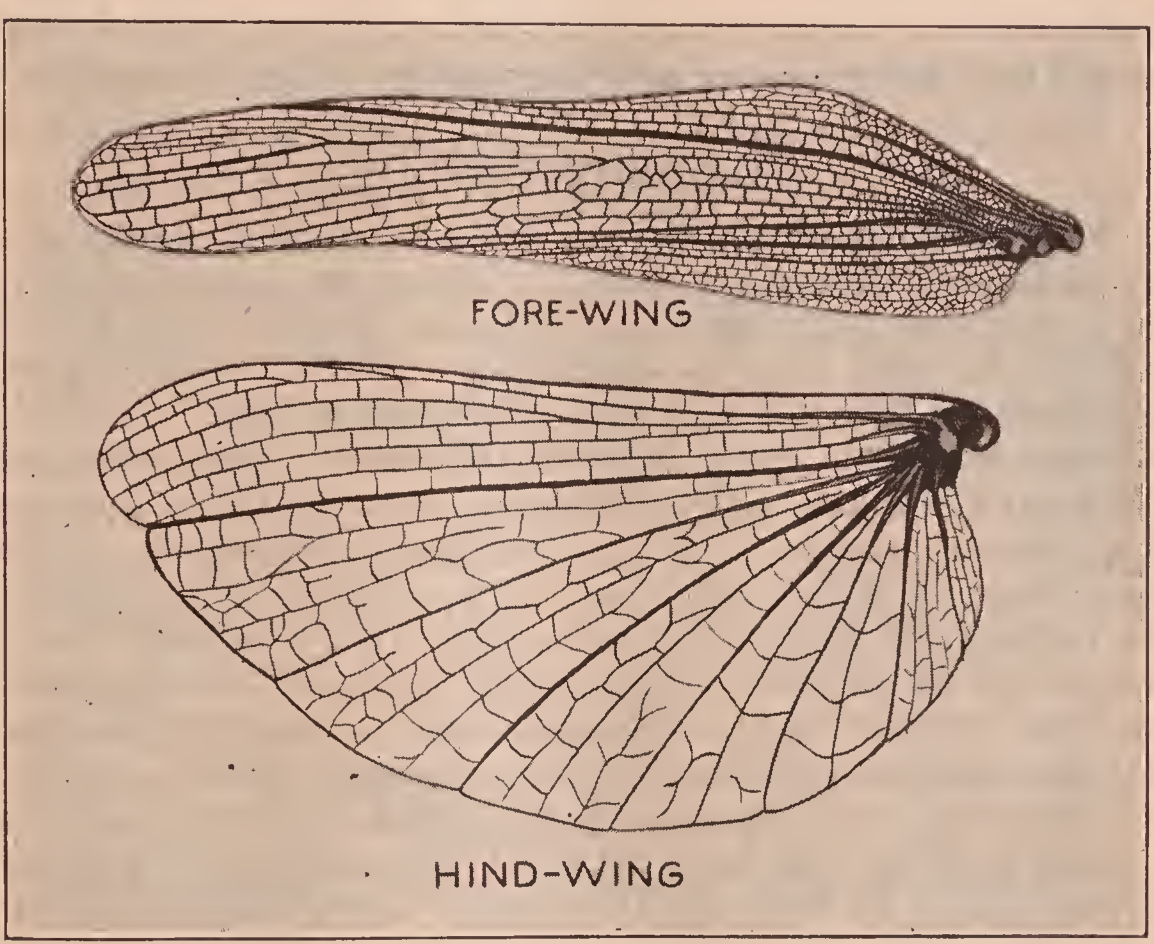


FIGURE 10. — FORE- AND HIND-WINGS OF THE GRASSHOPPER.
How does the grasshopper use each wing? What becomes of the hind-wing when the grasshopper is not flying?

mesothorax, provided with a second pair of legs and the first pair of wings, is not clearly separated from the third part of the thorax, the metathorax. This supports the jumping legs and the second pair of wings (the flying wings), which of all these appendages are the most used, and the most serviceable.

The Abdomen. — This third body region is clearly divided into ten segments. The first segment, a partial one, con-

tains the two auditory sacs, and two abdominal spiracles, one on each side. Fourteen other spiracles are found on the next seven segments, seven spiracles on each side. The last two segments have no spiracles. Instead they are modified for reproduction. The spiracles are used for breathing and the auditory sac, possibly, for hearing. In the female the last segment of the abdomen is provided with two pairs of blunt spines that serve as an egg-laying device called ovipositor.

LABORATORY STUDY

Work out the divisions of the body of the grasshopper: head, thorax, and abdomen; the position of eyes. How are the antennæ related to the eyes? How many distinct mouth parts are there? The teeth or jaws are the most useful in getting food. How do the jaws work? Sketch the head to show these parts with the mouth open.

Notice the attachment of the head to the thorax. The head fits into the thorax. The loose anterior (front) portion of the thorax is the prothorax (forward thorax). The first pair of legs is attached to it. Sketch the prothorax to show it and its legs. The portion of the thorax back of the prothorax is divided into two regions: the mesothorax (middle thorax) and the metathorax (back thorax). The line between them is not clear. Sketch these parts together with the legs and the wings. The jumping legs are attached to the metathorax; the outer wings to the mesothorax; the inner wings to the metathorax. The inner wings are used in flying. The leg of the grasshopper consists of: (1) a small section close to the body (the trochanter); a long muscular part free from spines (femur); a slender spiny part (tibia); and three segments of the foot (tarsus). The last segment of the foot is furnished with hooks which help the grasshopper in climbing, while the spines on the tibia prevent slipping as the grasshopper jumps. The large muscles in the femur of the last pair of legs, the spines on the tibia, and the hooks on the tarsus, are special adaptations which help the grasshopper in various ways.

Notice the tapering abdomen, composed of ten segments (rings), or parts of segments. Notice the depression and membrane in the first segment. This is the auditory organ, but it is not a true ear. Sketch the abdomen to show its features. The spiracles are located on the sides of the abdomen and thorax.

8. **Excretion.** — The gaseous waste, carbon dioxide, passes from the body into the spiracles and escapes into the air.

The liquid wastes are collected by urinary tubes that open into the intestine. If the grasshopper could not get rid of the waste substances that form in the body, it would be unable to live. If the grasshopper could use up entirely all the substances taken into the body, there would be little or no waste products. As the various nutritive substances become a part of the body of the grasshopper, some of the energy which they contain is so arranged that it cannot be used by the living cells of the insect. The grasshopper has organs of excretion which remove all these waste substances from the body.

9. Nervous System. — The fundamental life process of irritability (sensation) in the grasshopper is performed by the nervous system. It consists of nerves and ganglia arranged in a row beneath the digestive canal and in the head. Nerves connect this central chain of ganglia, which are masses of nerve cells, with all parts of the body. On the head are found compound and simple eyes, special organs for feeling, the antennæ, and organs of taste on the mouth parts. By means of all these specialized nervous organs, the grasshopper is able to see, feel, and taste with a high degree of efficiency. Through these senses and that of hearing, it is made aware of food and enemies.

10. Reproduction and Life History. — In the autumn the female lays from 25 to 100 eggs in shallow holes which she makes in the ground. Some grasshoppers lay their eggs in decayed logs. The following spring these eggs hatch into small, wingless grasshoppers called nymphs (nim′fs). (See Figure 11.) The nymph has a firm outer covering called an exoskeleton, which stretches but little with the growth of the nymph. Accordingly, at stated periods, the nymph sheds this exoskeleton, and grows for a time until it fills a new exoskeleton. This shedding or molting continues until the fifth and last molt, when the nymph becomes an adult provided with wings and mature in every sense.

Adult grasshoppers may be found during the summer in meadows, flying and crawling and feeding on the leaves of grass, grain, and other crops. At times the numbers may increase to such an extent that considerable damage is done

FIGURE 11. — GRASSHOPPER NYMPHS OF VARIOUS AGES.
How do they differ from the adult?

by them. The adults mate and the females lay eggs to provide for the next generation.

11. Metamorphosis. — All animals which pass through a marked change in external appearance as they become full grown are said to undergo a *metamorphosis* (mět-a-môr′-fō-sĭs: Greek, *meta*, change; *morphe*, form). These changes

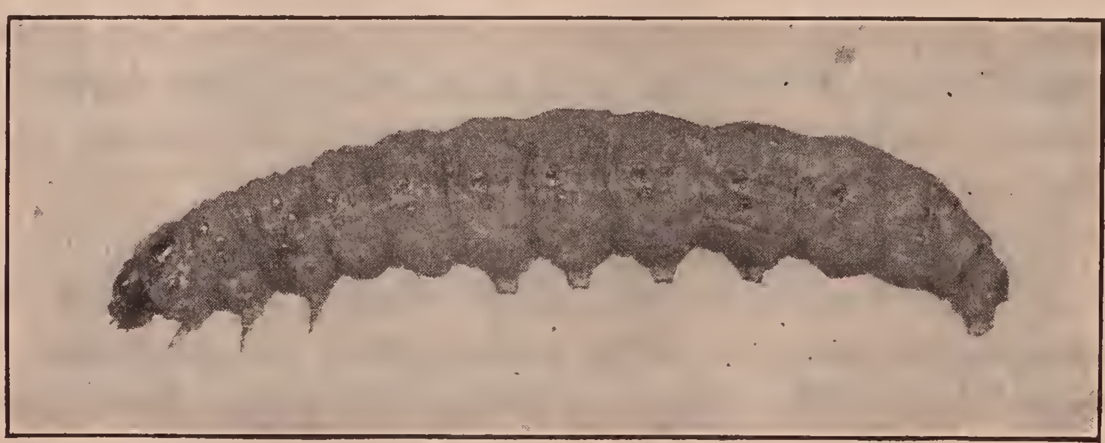


FIGURE 12. — CODLING MOTH LARVA (greatly enlarged).
Compare this immature insect with those shown in Figure 11.

are more marked in such insects as the ants and bees than in the grasshopper. For this reason we speak of two forms of metamorphosis — complete and incomplete.

12. Incomplete Metamorphosis. — The newly hatched grasshopper, while very small, looks enough like a wingless

grasshopper to be identified as belonging to the grasshopper family. Its form does not change materially from the time it is hatched until it is full sized. Thus the grasshoppers become adult by a growing process termed *incomplete metamorphosis*, showing no marked change in form (Figure 11).

13. Complete Metamorphosis. — Certain other insects, for example the codling moth, hatch into caterpillars from the eggs that the female lays in the apple. These caterpillars are known as larvæ (lär′vē: Latin *larva*, mask). The larvæ of the codling moth are the "worms in the apple." These larvæ are not recognized from their external appearance as young codling moths, yet that is what they are.

FIGURE 13. — "THE WORM IN THE APPLE," A CODLING MOTH LARVA.

What effect does it have on the apple?

As the larva eats a great deal, it grows rapidly, molting again and again until it becomes a full-grown caterpillar. It then eats its way out of the apple and finds a protected spot often under the loose bark where it weaves the silken covering, the cocoon (ko̤-kön′), about itself. In this cocoon it molts again. After this molt it has neither legs nor mouth parts and is known as a pupa. The pupa cannot eat, of course, but it continues to breathe. After varying lengths of time it molts again and the adult codling moth comes forth to fly and feed and prepare for another generation. Some larvæ that emerge from the late apples spin cocoons

FIGURE 14. — THE ADULT CODLING MOTH. How do we know that this animal is an insect ?

late in the fall and remain as larvæ in the cocoons all winter. They pupate in the early spring.

This series of changes through which the codling moth passes from egg into caterpillar, then into pupa, and finally into full-grown moth, is termed *complete metamorphosis.* Ants, bees, butterflies, beetles, and certain other insects undergo complete metamorphosis.

There are a number of different terms used to describe the larval stage of insects :

Larvæ:
- caterpillars are the larvæ of butterflies and moths.
- grubs are the larvæ of beetles.
- "wigglers" are the larvæ of mosquitoes.
- maggots are the larvæ of flies.
- currant-worms are caterpillars.
- measuring-worms are caterpillars.

14. Structure and Classification of the Grasshopper. — In order to understand the grasshopper more fully it is necessary to find its place in the classification of animals. All animals that are known have been grouped into classes for convenience in study. The grasshopper belongs to the large class of animals called *Insecta* (ĭn-sĕk′ta : Latin, *in*, in ; *seco*, cut.)

The *insects*, as a class, have their bodies divided into three regions — head, thorax, and abdomen. (See Figure 7.) All have three pairs of legs, and most of them two pairs of wings. They breathe by means of air tubes (*tracheæ*). In becoming adult, all pass through metamorphosis, either complete or incomplete. The insect group is subdivided into ten smaller groups or orders.

The grasshopper belongs to the order known as *Orthoptera* [1] (ôr-thŏp′tẽr-a : Greek, *orthos*, straight : *pteron*, wing). In the Orthoptera we find six common families: grasshoppers, crickets, katydids, cockroaches, walking sticks, and praying mantids.

15. Economic Insects. — By economic insects, we mean those insects which, by their activities, are either helpful or harmful to man. By saying that an insect has no economic importance we mean that it does not harm us by eating things useful to us and that it does not help us in any way.

The struggle to live is a problem for all animals, for man as well as for the grasshopper. All insects must eat, and some eat the same things we wish to eat. Such insects we call harmful. Others aid the growth of plants by carrying the pollen dust from one flower to another; others make honey. Such insects are useful. Certain other insects, like the fly, carry the germs of disease. These insects are particularly harmful, for they cause sickness and death.

Certain beetles eat dead flesh or bury dead animals by tunneling under them. Such insects are helpful. We should study insects in order to find out which are our friends and which our enemies. It would not do to kill all kinds of insects, for in many cases we should harm ourselves.

16. Economic Phases of the Grasshopper. — The grasshopper eats the leaves of plants, and if there are many grass-

[1] grasshoppers, katydids, crickets	(straight wings)	Orthoptera
butterflies and moths	(scaly wings)	Lepidoptera
beetles	(shield wings)	Coleoptera
bugs	(half wings)	Hemiptera
bees, wasps, ichneumones, gall flies	(membrane wings)	Hymenoptera
flies and mosquitoes	(two wings)	Diptera
dragon flies	(teeth)	Odonata
May flies	(short lived)	Ephemeridæ
stone flies	(net wings)	Plecoptera
fleas	(wingless)	Aptera
	often called siphon-mouthed	Siphonaptera

hoppers they cause a serious loss of crops. The plague of locusts mentioned in the Bible refers to grasshoppers. In some of the Western States years ago the grasshoppers came in great swarms year after year and destroyed annually crops estimated to be worth $200,000,000. But ordinarily, owing to the activities of their natural enemies, the number of grasshoppers does not become alarming.

FIGURE 15. — MODERN SPRAYING OUTFIT.

This invention enables us to destroy harmful insects on our largest trees. There are many different kinds. Every city should have one. The farmer who raises apples, pears, and other fruits has to spray his trees every season, if he expects to have fine fruit to market.

Among the natural enemies of these insects that do much toward reducing their number are the birds. Some of the greatest destroyers of grasshoppers are the quail, bluebird, sparrow hawk, butcher bird, crow, red-winged blackbird, and kingbird. The crows, because of their large size and great numbers, probably kill the most grasshoppers.

Other members of the order Orthoptera, that are harmful, are the cockroaches, the nuisances of the pantry, and the crickets that eat the roots of plants. There are also tree crickets which frequently lay their eggs in raspberry cane and this injury kills the cane above the place where the egg is laid.

17. What Has an Animal like the Grasshopper Accomplished by Living? — (1) It has used plants as food to build a complex body. (2) It has produced more grasshoppers. (3) It has used some stored-up food which might have been useful to cattle or sheep. (4) It has set free waste carbon dioxide which can be used by green plants to assist them in making food. (5) When it dies and decomposes, its chemical substances are returned to the soil and air to be used again by other living things.

QUESTIONS

What are the most important things that the grasshopper must do to live?

How is the grasshopper protected? How does the grasshopper breathe? How get its food?

How does the grasshopper begin life?

Define metamorphosis. How many kinds of metamorphosis are there? Which kind does the grasshopper show?

Is the grasshopper a friend or an enemy to man? Why?

CHAPTER II

IMPORTANT AND FAMILIAR INSECTS

In the preceding chapter we studied the grasshopper, a typical member of the Orthoptera. We shall now take up several other orders of insects, with most of which we are already familiar.

18. Hemiptera. — Another common order of insects is the *Hemiptera* (hĕ-mĭp′tẽr-a: Greek, *hemi,* half; *pteron,*

FIGURE 16. — SCALE INSECTS PHOTOGRAPHED ON A FERN FROND.
The insects are oval in outline and colored so that they look much like the green frond upon which they are feeding.

wing). To this order belong such common insects as the cicadas, plant lice, the woolly aphis, and the bane of the orchard, the San José (săn hō-sā′) scale. Some of these are very harmful. When the San José scale is allowed to feed freely, whole orchards may be destroyed. Plant lice

injure apple, cherry, and peach trees, and the cabbage plant. The several kinds of scale insects which harm orchards may be killed by spraying the trees with a solution of lime and sulphur.

19. Cicada. — One of the most interesting insects of the Hemiptera is the seventeen-year cicada (sĭ-kā′da), commonly called the "seventeen-year locust." The name is given to it because the nymphs (nĭm′fs, the immature stage) remain in the ground, actively feeding on roots, for seventeen years. There is another kind of cicada that remains in the ground for thirteen years.

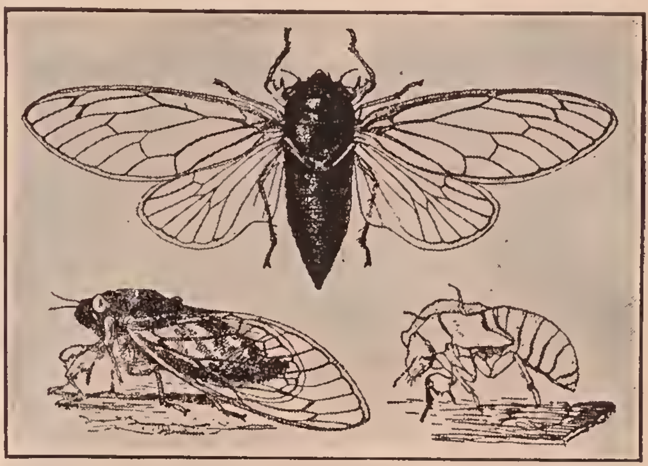


FIGURE 17. — ADULT SEVENTEEN-YEAR CICADA AND NYMPH.

These insects, commonly called locusts, were abundant in the early summer of 1919 in the Eastern and Middle-Western States. Did you see any of them? If you did not, you will have to wait seventeen years before you have another chance. There may be other breeds in the vicinity.

Every thirteen or seventeen years, generally in the month of May, the nymphs crawl out of the ground, climb trees or fences, and molt into adult cicadas. The adult females lay their eggs in tender shoots of trees, causing the shoots to die. The young cicadas, after hatching in the shoot of the tree, go into the ground and begin their long period of larval existence which lasts thirteen or seventeen years. These cicadas are usually found in limited areas, but in these areas are very numerous.

The cicadas which we hear every summer are another kind, whose nymph lives in the ground for two years. As there are two broods of this species that appear in alternate years, the number does not seem to vary from year to year. Birds do much towards destroying them, the kingbird, sparrow-

hawk, butcher bird, and great-crested flycatcher being their most common enemies.

20. Coleoptera. — The Coleoptera (cō-lē-ŏp′tẽr-a: Greek *coleos*, shield; *pteron*, wing) are the beetles. The first pair of wings is horny and meets in a straight line down the back. The second pair of wings consists of thin membranes. The mouth parts are for biting. Among the harmful beetles are many wood borers, the May beetles, potato beetles, asparagus beetles, and weevils. Some of the beneficial beetles are the ladybug, which feeds on destructive and harmful insects, and the carrion beetle, that feeds on dead animals.

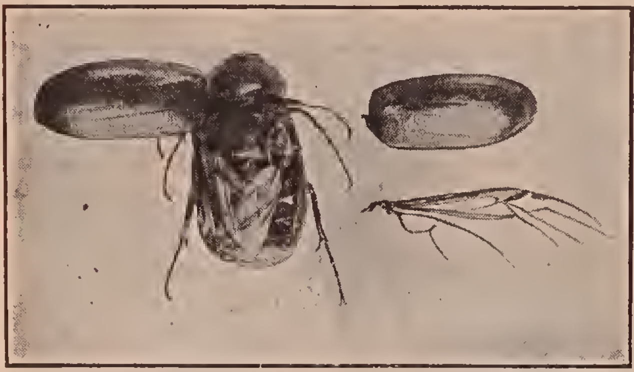


FIGURE 18. — MAY BEETLE.

This is one of the commonest members of the Coleoptera. Note the anterior wings which are shield-like and serve for protection. How do they differ from the second pair?

The ladybugs are decidedly beneficial. Their larvæ run over leaves and feed on other insects. Even as adults they continue this good work. Hop growers appreciate the value of the ladybug larvæ on their vines, as the ladybugs destroy the harmful hop lice.

Through the investigations of the United States Department of Agriculture a certain kind of ladybug (Vedalia) was found in Australia, which is the natural enemy of an insect pest (cottony cushion scale) that was destroying the orange trees grown in California. This scale is a plant insect which was imported into the United States on young trees. Being freed from their natural enemies (Vedalia) which were not imported, they had increased rapidly. The prompt importation of Vedalia put an end to the increase of the cottony cushion scale and they are now of no great economic importance.

The bird enemies of the beetle are numerous. Among the most important are the ring-necked pheasant recently introduced, the rose-breasted grosbeak, and the quail, which feed particularly on potato beetles. The English sparrow, cuckoo, and kingbird feed on the weevils. Robins, blackbirds, and crows eat the white grubs, the larval stage of the May beetles. The woodpeckers destroy great numbers of borers by digging holes in the trees where the borers are tunneling.

21. Potato "Bug" or Potato Beetle. — The potato beetle arrived in New York State from the West in 1872. Originally the beetle was found in Colorado feeding on wild plants of the potato family, whence its name of Colorado beetle. It gradually made its way east from one potato patch to another, being helped by the wild plants of the potato family that grew where there were no potatoes. These beetles were also carried by trains that in a few hours took them hundreds of miles.

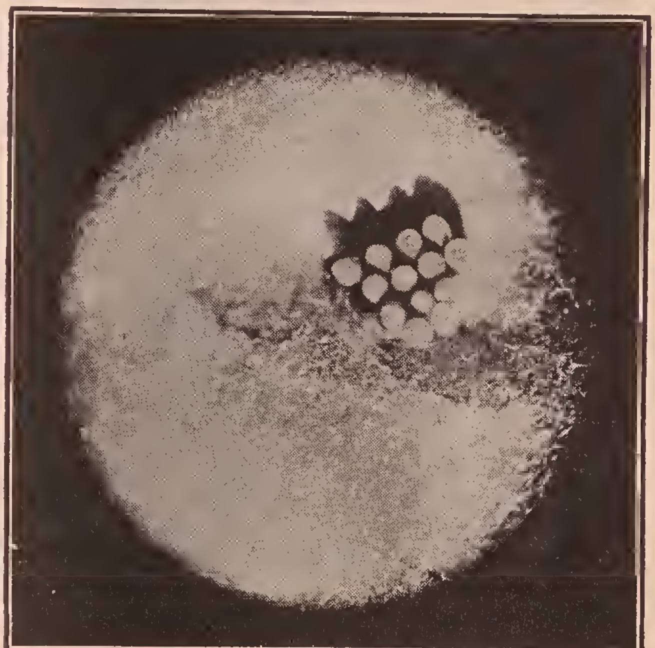


FIGURE 19. — EGGS OF LADYBUG (greatly enlarged).

You will need sharp eyes to find them in nature.

22. Damage. — The potato beetle eats the foliage of the potato plant, thus injuring the size and quality of the tubers. This is due to the fact that most of the starch stored in the tuber is produced in the leaves and when the leaves are destroyed the amount of starch available for the tuber is lessened. Spraying must be carried on wherever potatoes are grown, to insure a good crop.

23. Life History of the Potato Beetle. — The adult potato beetle passes the winter in the ground. In the spring the

adults crawl out of the ground and the females lay their orange-colored eggs on the under side of the leaves of the early potatoes. In about a week or ten days the eggs hatch and the larvæ eat ravenously. In two or three weeks the larvæ reach their full size. They make their way into the ground, where they pupate for two weeks or longer, depending on the temperature. At the end of the resting stage, they emerge as adults and the females lay their eggs on the late potatoes for a second generation. The eggs hatch into larvæ, the larvæ pupate in the ground, and the adults emerge in the fall. At the beginning of the cold weather the adults enter the ground and hibernate through the winter.

FIGURE 20. — MONARCH BUTTERFLY.

It is here seen feeding on the flower of the red clover. What is it eating?

24. Natural Enemies. — It is fortunate that the potato beetle has so many natural enemies. Adult lady beetles, popularly called "ladybugs," and their larvæ kill many of them. The tachina-flies lay eggs on the potato beetle larvæ and the young tachina-flies in the form of larvæ burrow into the bodies of the beetle larvæ, killing them in great numbers. Toads and snakes are enemies of the potato beetle and they take a heavy toll of them. The skunk is another enemy of the potato beetle, while crows, rose-breasted grosbeaks, pheasants, and quail destroy them in great numbers.

25. Life History of the Monarch Butterfly. — The monarch butterflies arrive in the Northern States from the South, usually in June. Very soon the females lay eggs on the different kinds of milkweeds. The eggs hatch in a few days,

—the time depending on the temperature—into caterpillars that feed on the leaves of the milkweeds. Each caterpillar has three pairs of jointed legs near the head and five pairs of leg-like structures along the posterior region that serve for clinging. The caterpillar (larva) molts and each time grows larger but does not show any signs of wings like the grasshopper. It is merely a larger caterpillar.

FIGURE 21. — LARVA OF THE MOURNING CLOAK BUTTERFLY.

It is gradually transforming into the pupal stage.

In *A* notice the curve in the body of the larva and the attachment at the top. In *B* note that the exoskeleton first breaks on the back near the head. In *C* the exoskeleton is being forced up toward the attachment at the top. In *D* the whole of the larval exoskeleton is removed and is shown shriveled at the right. In *E* the chrysalis is shortening and curving to the right. Compare *E* and *A*. Note that the short projections on the left of *E* are not on the same side as the feet in *A*. Compare with Figure 22. In *F* the chrysalis is still further shortened and curved.

Just before the fourth molt it attaches itself to a leaf or stem and hangs by a knot of silk with its head down for a few days until it molts for the fourth time. After this molt it is a pupa without legs or mouth parts. It is yellowish green in color, with golden spots. During this stage there is a striking change taking place inside the green covering. Wings, new legs, different mouth parts with a long coiled tongue, and a nervous system of a different form are growing into working order while this pupa hangs so quietly. After a few days the green pupa case breaks open and the adult crawls out with the wings crumpled. Within a few hours the wings expand and push out the wrinkles and it is ready to fly away to feed on the nectar of flowers. This is an example of complete metamorphosis. (For explanation of metamorphosis see §§ 11, 12, 13.)

FIGURE 22.—TRANSFORMATION OF PUPA OF MOURNING CLOAK BUTTERFLY INTO ADULT.

In *A* notice the form of the chrysalis. Notice the points on *A* towards the left. What are they? Do they indicate the position of feet? See if this question is answered in *C*. How does the real position of the feet compare with their position in *A* of Figure 22? In *D* notice the folds in the wing near the end. In *E* notice that the scale of reduction is different. The chrysalis cover in *E* is the same as in the other pictures. The camera had to be moved back to include the whole of the butterfly after it had fully expanded.

LABORATORY STUDY

The adult monarch butterfly has the body divided into head, thorax, and abdomen. How do these parts compare in size with the same regions in the grasshopper? Compare the legs and wings with those of the grasshopper. Which of these two insects is better adapted to flying? To jumping? Draw the entire animal. Draw wings and legs.

Gently rub the finger on the wing, and as the dust comes off, the wing looks more like the wing of a fly or bee. The lines that run lengthwise of the wing are the veins. Draw the wing.

The mouth parts of the butterfly are united into a single long tube which is the coiled tongue-like structure, called the proboscis (prō-bŏs′ĭs). Unroll it and see how its length compares with the length of the body. The butterfly uses the proboscis to suck nectar from flowers. Compare these mouth parts with those of the grasshopper.

FIGURE 23. — CECROPIA MOTH.

A, larva; *B*, pupa; *C*, cocoon; *D*, adult. How does this form of metamorphosis differ from that shown by the life history of the grasshopper?

26. Lepidoptera. — The Lepidoptera (lĕp-ĭ-dŏp′tĕr-a: Greek, *lepido-*, scaly; *pteron*, wing) include the familiar moths and butterflies. Some of the members of this order, such as the adult peach-tree borer, look more like wasps than like moths. There are more harmful insects in the order of Lepidoptera than in any other order. Among the particularly destructive members are the insects which are commonly called codling moths, gypsy moths,

Figure 24.—Redheaded Woodpecker Eating Suet Placed in a Hole.

Figure 25.—Young Tobacco Worm, a Caterpillar.

One of its insect enemies has laid eggs in its body which have hatched into caterpillars. These caterpillars in turn have fed upon the tobacco worm until it was time for them to pupate. They then ate their way out of the body of their host and spun their cocoons which are attached to the surface of the body. What will happen to the tobacco worm?

Figure 26.—One of the Swallowtail Butterflies (not common).

Notice that the tongue is extended by means of loop of wire. This gives an idea of the length of the tongue in comparison with the body. This tongue enables the butterfly to gather nectar from flowers with long nectar spurs.

Figure 27.—Larvæ of Leaf Miner at Work in Elm Leaf.

The larvæ are between the upper and lower transparent epidermis of the leaf. They have eaten all the inner layers of the leaf, see Figure 263.

brown-tail moths, tent caterpillars, cut-worms, army worms, and canker worms.

But not all the Lepidoptera are harmful. Many of the most beautiful moths and butterflies develop from larvæ that do no particular harm. Their natural enemies, such as birds and *Ichneumones* (ĭk-nū′mō-nēs) (see § 31, page 51), keep their numbers reduced. Among the more strikingly colored butterflies are the black swallowtail, the larvæ of which feed on celery, parsley, and carrots; and the monarch or milkweed butterfly.

As the butterfly goes from flower to flower after nectar, its head brushes against the parts of the flower that grow the pollen dust. The pollen is thus carried from one flower to another, and this helps the flower to grow better seeds.

FIGURE 28. — WINGLESS FEMALE OF TUSSOCK MOTH.

She is laying eggs on the cocoon from which she has just crawled. After the eggs are laid, she moves around for a short time and dies of starvation if some bird does not find her in the meantime.

27. Enemies of the Lepidoptera. — The numerous enemies of the Lepidoptera prevent them from becoming a scourge. Chief among these enemies are the *Ichneumones*, members of the order Hymenoptera (Figure 43). Ichneumon (ĭk-nū′mọn) adults lay their eggs on the body of many caterpillars. When these eggs hatch into small larvæ Ichneumones, the larvæ eat their way into the body of the large caterpillar, where they live feeding upon its body juices. These ichneumon larvæ are called *parasites* because they derive their food from the caterpillar. The caterpillar which contains these ichneumon parasites is called a *host*.

The ichneumon parasitic larvæ grow rapidly and before the caterpillar dies they reach the stage at which they

turn into pupæ. When they are ready to pupate, they eat their way out of the body of the caterpillar and spin a cocoon which in some cases remains attached to the body of the caterpillar (Figure 25). These parasitic larvæ so weaken the caterpillar that it dies. We shall learn more of these Ichneumones later.

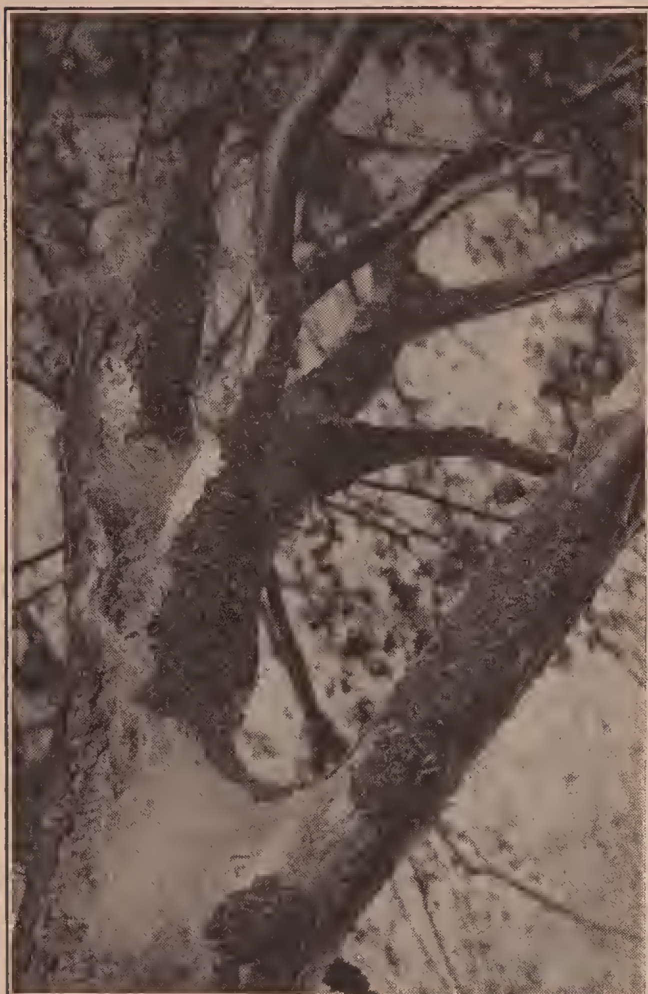


FIGURE 29. — TENT CATERPILLARS.

They are seen resting during the hotter part of the day on the trunk of the apple tree. Later in the day they go out and eat the foliage. Note the great blankets of silk that they have spun on the side of the tree. Fortunately most of these caterpillars were attacked by ichneumon-flies, tachina-flies, and chalcis-flies so that very few matured. The year following these destructive insect pests did very little damage owing to the successful campaign of their numerous insect enemies.

Next to Ichneumones, the birds are probably the most active enemies of the Lepidoptera. Many birds live entirely upon caterpillars and we find birds that seek them as food in all stages of their development and growth. The eggs laid on the twigs and trunks of trees are eaten by chickadees, nuthatches, brown creepers, and woodpeckers. The larvæ are eaten by many birds, notably by cuckoos, bluebirds, wrens, blackbirds, orioles, blue jays, crows, and house sparrows. The cocoons and pupæ are sought by the chickadees, woodpeckers, nuthatches, and brown creepers. The adult insects are preyed upon by house sparrows, chipping sparrows,

and the whole group of flycatchers, including the kingbirds and phœbes.

28. Codling Moth. — The most destructive of the lepidopterous insects is the codling moth, already mentioned as an example of metamorphosis. The larvæ become adult in April at about the time the early apple trees blossom. The eggs are laid on the young apples and the larvæ begin to eat the growing apple, which, as a result in many cases, drops to the ground. In any event the quality of the apple is injured.

FIGURE 30. — CEDAR WAXWING.
Feeding its young a flying insect. One of our most beneficial birds.

After these larvæ become mature they escape from the apple, spin their cocoons, and in a few days emerge as adults. They mature about the time the late apples are blossoming or later and the females lay their eggs either in the blossoms or on the small fruit. The same damage is done as to the early apples, but as each mature female lays a hundred or more eggs and as the most important apple crop is the late one, the chief damage is at this time.

In one year the injury done by the codling moth to the apple and pear industry in New York State alone amounted to $3,000,000. By applying a spray containing some poison just after the petals have fallen, the codling moths may be destroyed. The spray should not be used while the blossoms

FIGURE 31. — PROTECTIVE COLORATION.

Explain how the Army used this scientific fact in the recent war.

are fresh, because then the helpful bees which visit them are killed, and no harm is done to the destructive codling moths that come later.[1]

FIELD, LABORATORY, OR HOME STUDY OF MOTHS AND BUTTERFLIES

These insects are easily collected and are interesting to study. From late in the spring until October you can find larvæ and pupæ. Some of the leaves upon which the larvæ are feeding should be collected.

The larvæ should be placed in jars provided with soil and some leaves. Arrange the cocoons and pupæ which you find as suggested in the following table.

Cocoon			Pupa			
Spun with silk only	Spun with a leaf	Spun with hair	Without cocoon	Suspended from one end	Suspended from one loop	Parasitized

Tent caterpillars spin cocoons and form small brown moths. Celery "worms" hang in a loop and form a black, swallowtail butterfly which feeds on the nectar of lilacs and the rhododendrons of city parks.

The black spiny caterpillars of the willows and elms hang free from the knot of silk and form the mourning cloak butterfly.

Tomato "worms" burrow into the ground and form a large-bodied, small-winged moth, a sphinx moth.

[1] The life history of the peach-tree borer may be assigned in this connection.

29. Hymenoptera — The Honey-bee. — In contrast to the Lepidoptera, which, as has been said, are probably the most destructive order, we find the Hymenoptera (hy-mĕn-ŏp′-tẽr-a: Greek, *hymenos*, membrane or thin skin, *pteron*, wing) that are of the greatest value to man. This order includes the bees, wasps, ants, Ichneumones, and the like. The honey-bee and the bumblebee are the most important of the bees. The honey-bee is valuable for its honey and wax, and as a distributor of the pollen which is necessary to produce seed. The bumblebee is valuable mainly as a distributor of pollen.

FIGURE 32. — YELLOW SWALLOWTAIL, GATHERING NECTAR FROM LILACS.

Honey-bees afford a splendid example of community life among insects. In the wild state they live in trees and caves. All wild honey-bees in this country have escaped from hives.

FIGURE 33. — *a*, HONEY-BEE WORKER; *b*, QUEEN; *c*, DRONE. Twice natural size.

In a honey-bee colony there are three classes of bees, — the perfect females or queens, the males or drones, and the imperfect females or workers. There are generally one queen, a few hundred drones, and twenty to fifty thousand workers.

FIGURE 34. — THREE QUEEN CELLS.

In the brood comb of the honey-bee.

The queen alone can lay eggs. She can lay an unfertilized egg which hatches into a drone, or she can lay an egg which is fertilized. This fertilized egg hatches into a queen or a worker, according to the food and the size of the cell which are provided by the workers. Thus the decision as to whether the young bee shall be a queen or a worker rests with the workers themselves. They also have the power to supersede the queen, or to raise a new queen in case of the sudden death of the old one. These powers are rightly intrusted to the workers — the great majority.

The eggs are placed by the queen in cells, and, after hatching, are fed by the young workers, called nurses. The larva is fairly bathed in food. In a few days the larva is full grown, and then pupates. The workers now cap over the cell with wax, and in about twenty-one days the young bee cuts away the cap and crawls out — an adult provided with the four wings, mouth parts, antennæ, and six legs of the honey-bee.

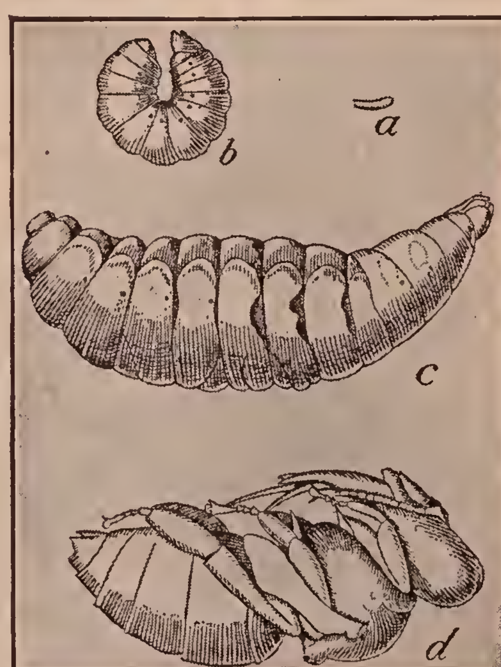


FIGURE 35. — *a*, HONEY-BEE EGG; *b*, YOUNG LARVA; *c*, OLD LARVA; *d*, PUPA.

Three times natural size.

Workers are provided with the sting which is a weapon of both defense and offense. The queen

has a small sting, and the drones have none. When bees sting large animals, like men, horses, and dogs, their sting is pulled out and with it parts of the internal organs, thus causing the death of the bee. When bees sting other insects, or even one another, their sting is not lost.

Sometimes swarms which have few bees and little honey are attacked by bees from other colonies. It is a pitched battle until the "robber bees" are beaten back or the defenders are themselves killed. The sting is used in these battles.

Bees are instinctively sanitary. If a large bumblebee enters the hive, the bees kill the intruder and usually, finding him too large to be taken out, embalm him by injecting the sting repeatedly into his body. The result of this operation is to make the bumblebee harmless to the colony. Sometimes they cover the body of a small, dead animal with a case made of *propolis* (prŏp'ō-lĭs), a substance the bees gather from certain buds. This serves to protect the colony from the effects of the decomposition of the body.

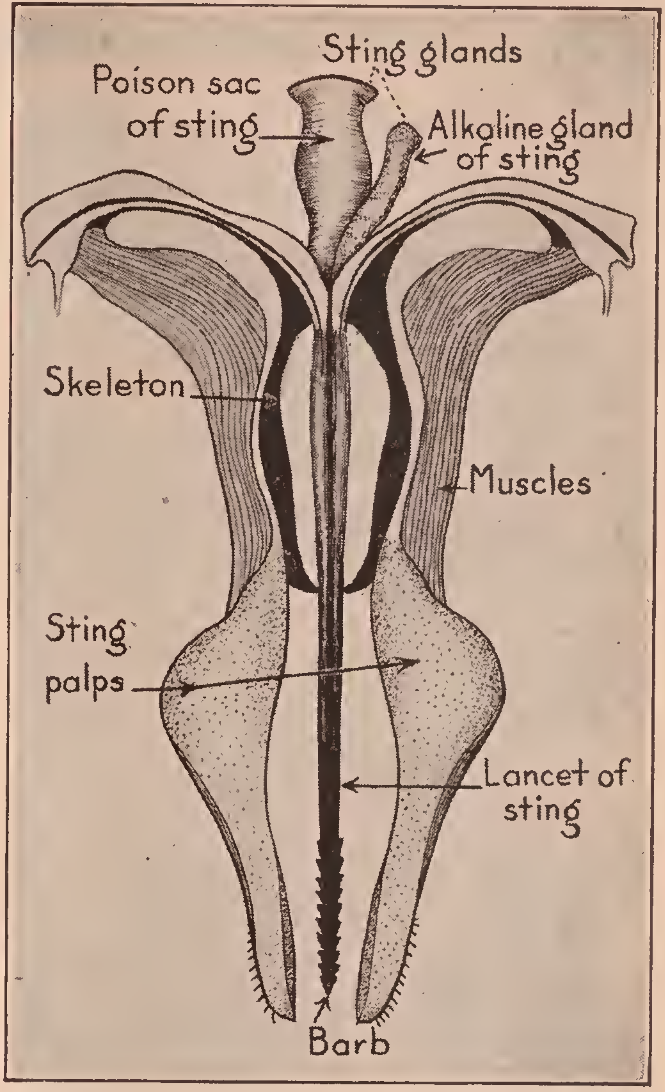


FIGURE 36. — THE BEE'S STING.

It is provided with barbs and a small amount of formic acid as an adaptative feature. Being located at the end of the abdomen, it can be turned in any direction. Notice the barbs on the sting. These point backwards and are adapted to cling to the surfaces through which it is forced.

At irregular intervals during the early spring and summer, bees have the peculiar habit of *swarming*. Several reasons for swarming are given by bee-keepers, but no one pretends to be certain that he really knows the cause. It is a sort of revolt of the bees against their condition. Two of the commonest reasons given to explain swarming are the lack of room for the growing colony, and lack of food.

FIGURE 37. — HONEY-BEES CLUSTERING AT SWARMING TIME.

When bees swarm, they usually alight on the limb of a tree and form a dense cluster. Here they hang from fifteen minutes to an hour before leaving for the woods. In a few cases bees have remained in this "cluster" state overnight, but usually they are lost unless they are collected inside of half an hour. The swarm consists of a large number of adult bees, workers, and drones, and usually a single queen.

Various devices against swarming have been invented, but the most effective is to clip the wings of the queen in order that she may be kept at home, because the other bees usually follow her. This is done after the queen has taken her "wedding-flight." Her wings are clipped close to the body, but only on one side. The bees that then swarm soon come back and are easily controlled. While the bees are still in the air, a clean, empty hive is placed

where the old one was. Bee-keepers, during the swarming period, always have a number of empty hives in position ready for the swarm to occupy.

The returning bees enter the new hive in search of the queen. As they are rushing in, the queen with clipped wings is released, and she, in turn, joins the procession and enters with the others. Having found the queen and plenty of room, the colony is usually content to remain. Sometimes swarming becomes a mania with certain colonies, and it is difficult to get them to settle down contentedly in a hive and make honey. Runaway swarms have to be watched with great patience. Bees that have been raised for many bee generations in man-made hives sometimes leave suddenly and seek out a hollow tree in the forests.

FIGURE 38. — CAPTURING A SWARM.

The length of the bee's life varies. The drones are usually killed at the end of their first season. Queens live for five or six or even ten years. Workers live three or four weeks in the working season and several months in the fall or winter.

The honey and wax produced annually in the United States are valued at $22,000,000.

30. Adaptation Shown in the Honey-bee. — The tongue is adapted to getting nectar from certain flowers like apple

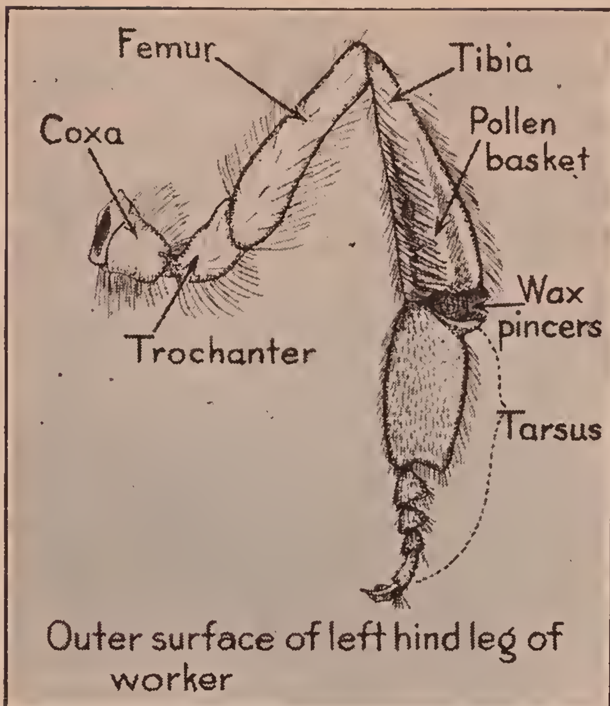


Figure 39 A.

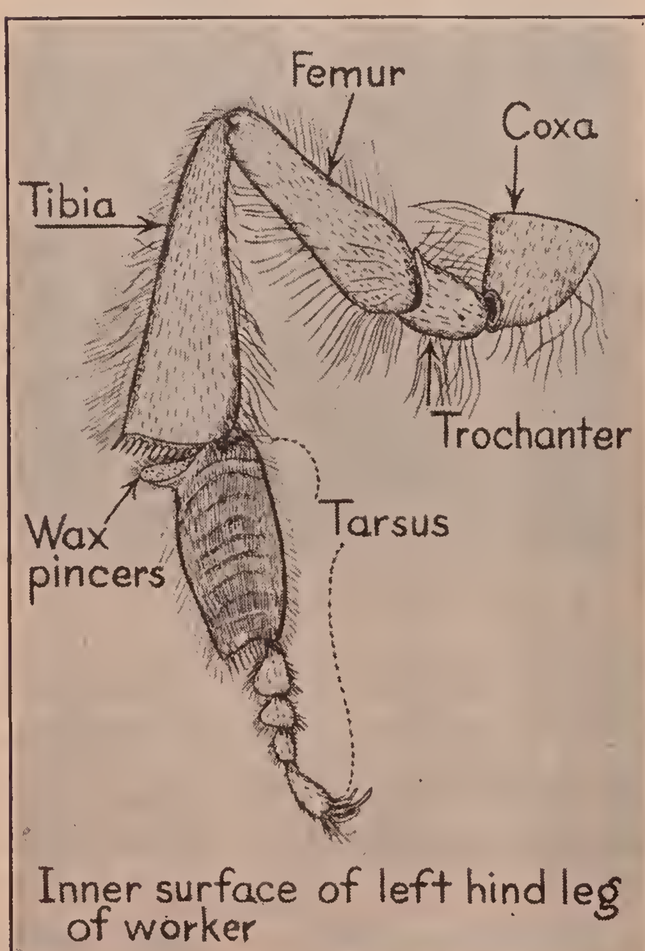


Figure 39 B.

blossoms, lindens, white clover, and sweet clover. It is too short to get nectar from red clover blossoms. The mandibles are adapted to gathering propolis from buds, also for kneading the wax and for polishing surfaces. The wings are adaptations for the particular life of the honey-bee. In the first place they are small, and are not likely to be injured when the bees are packed closely together as in swarm clusters. Then, to compensate for the small size, they are vibrated with great rapidity to carry the bees through the air with a load of nectar and pollen. Sometimes they vibrate 440 times per second.

The last pair of legs is adapted not to jumping, as in a grasshopper, but for carrying loads of pollen and propolis. These legs are flat and thin and provided with bristles to keep the load from sliding off.

31. Ichneumones. — Another interesting division of the Hymenoptera includes the Ichneumones. We have already seen (page 41) how they help to keep the Lepidoptera from becoming a scourge. They also furnish other interesting examples of parasitism. As an illustration we may use one of the larger ones known as *Thalessa.* With long, thread-like drills this parasitic insect bores holes in trees, and lays an egg at the bottom of the hole. The egg is usually laid near the burrow of one of the larger tree borers, the *Tremex.*

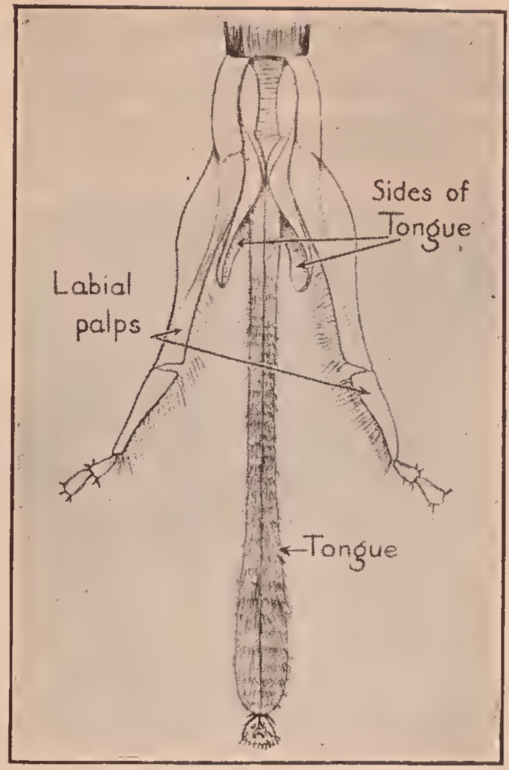


FIGURE 40. — TONGUE OF HONEY-BEE.

Notice the numerous hairs of the tongue and palps.

FIGURE 41. — MODEL APIARY.

The larva of the Thalessa makes its way along the burrow of the Tremex borer and fastens itself to the body of the borer, where it feeds upon the borer and thus kills it. In time the adult Thalessa emerges, ready in turn to do its part in laying eggs which will destroy more of these enemies of the tree. But if the Thalessa parasites kill the Tremex borer before it has eaten its way through the hard wood, then all die together, because the Thalessa cannot cut an opening for itself.

FIGURE 42. — WORKER HONEY-BEE LADEN WITH POLLEN.

32. Ants. — The ants are insects which live in large families. Each family has many workers, and a number of queens and males. Certain kinds have, in addition, their soldiers which have strong mouth parts (mandibles). The soldiers do the fighting for the colony. Some ants are winged and others are wingless.

33. Life History of the Ant. — In most ant colonies there are several queens. Unlike the honey-bees, several queens live in harmony in an ant colony. The ant eggs are so small that they are scarcely visible to the unaided eye. The legless larvæ hatch in a few days, being full grown in about two weeks. Pupation lasts about two weeks. The cocoons are

FIGURE 43. — THALESSA LAYING EGGS. The tree is infested with Tremex.

the white objects which are commonly called "ant-eggs." The adults guard these cocoons which contain the pupæ, carrying them away to places of safety when the colony is disturbed. Sometimes the adult workers remove them to warmer quarters.

The males and females have wings while the workers are wingless.

FIGURE 44. — TREMEX.

Just after laying eggs in a tree. The larvæ of this insect do much damage to trees.

34. Behavior. — Many interesting facts about the honey-bees are well known while less attention has been paid to the ants although these seem to be even more wonderful insects. Some of the interesting facts about ants follow:

1. They build beaten roads with tunnels under brushpiles.

2. They keep plant lice for the sweet fluid they exude which suggests the keeping of cattle by man.

3. They carry these plant lice into their tunnels and care for them over the winter season. In the spring they carry them out and place them on food plants.

4. If a nest is attacked by enemies, the soldiers rush around and stroke the workers with their antennæ. This seems to inform them of the attack and they hurry to the rescue.

5. They wrestle and play and sometimes carry one another around. It looks like a football game.

6. They have battles with other colonies. Before a

battle starts they send out scouts. They await the return of the scouts before they begin the battle.

7. When one colony subdues another in battle, the victors take home the larvæ and pupæ of the vanquished and bring them up to be slaves. The slaves seem to be loyal to their conquerors and to take great interest in the welfare of the victorious colony.

8. Among certain kinds of ants the slaveholders have depended so long on the slaves that they are unable to build nests or even feed themselves. If the slaves are taken away, the slaveholders starve. The slaveholders are able to fight, however, to get more slaves.

35. Diptera. — The Diptera (dip′ter-a: Greek, *di-*, two; *pteron,* wing) include such harmful insects as the mosquito, house-fly, bot-fly, and cheese-skipper; also the beneficial bee-fly, wasp-fly, and tachina-fly.


FIGURE 45. — COMMON HOUSE-FLY.

One of the most important members of this group is the common mosquito, which lays from two hundred to four hundred eggs in a raft-like cluster on the surface of the water in any stagnant pool or rainwater barrel. These eggs are usually laid early in the morning and, in favorable weather, hatch the afternoon of the same day. The wigglers (larvæ) keep to the surface when breathing but swim freely in the water for food. Food is brought to the mouth by vibrating cilia, which keep a current of water passing near them. From this water the wiggler collects his food. After seven days of this life it becomes a pupa, which, unlike most other pupæ, can move about. The pupæ remain at the surface of the water for air but descend by swimming when disturbed. The pupa stage lasts for two days, when the adult emerges and flies away after its wings are dried.

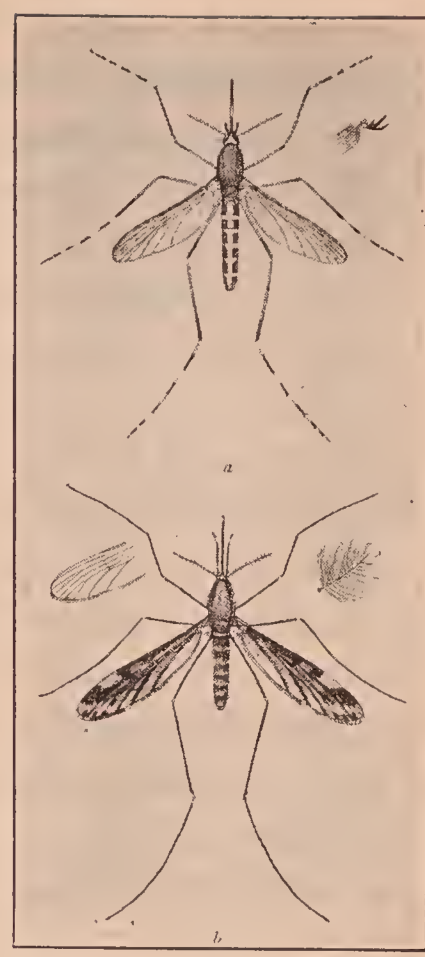


FIGURE 46. — CULEX AND ANOPHELES.

The time of these changes from egg to larva, from larva to pupa, and from pupa to adult depends on the temperature. Warm weather shortens the time and cold weather lengthens it.

In the United States there are three distinct kinds of mosquitoes. (1) The common mosquito is known by the technical name of *Culex* (kū′lĕks). It is not known that the Culex carries in its body any disease germs harmful to men, therefore it is regarded as harmless, although a source of great annoyance to those who frequent the woods or seashore during the summer. (2) *Anopheles* (ȧ-nŏf′e-lēz) is the scientific name of a second kind of mosquito, which is also generally distributed, but is not so numerous as the Culex. The Anopheles often carries in its body the germs that cause the disease called *malaria*. (3) *Stegomyia* (stĕg-o-mī′yȧ) is a mosquito common in the southern part of the United States. It is the insect which carries the germs of yellow fever from one person to another.

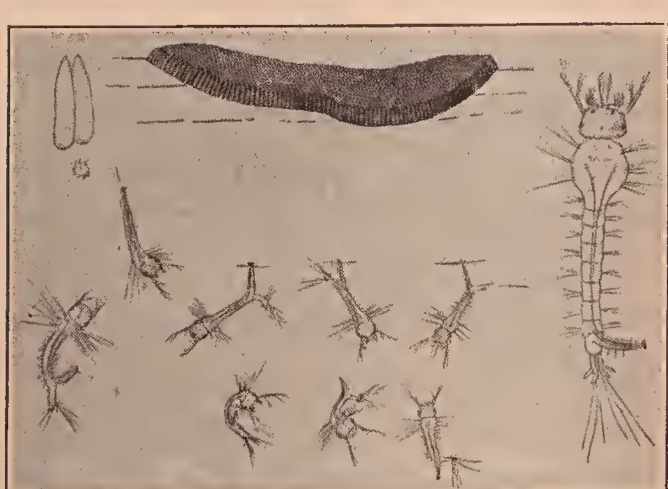


FIGURE 47. — EGGS AND LARVÆ OF CULEX.

It is fortunate that the mosquitoes have so many enemies. The "wigglers" are preyed upon by the larvæ of the dragon flies, by small fish, and by water beetles; while the adults

are eaten by nighthawks, martins, bats, and dragon flies. Certain diseases caused by plants attack the adults and kill them in great numbers. (See Chapter XXIII.)

The number of mosquitoes can be greatly reduced by destroying their natural breeding places in old rain barrels, watering troughs, boxes that may hold water, pails, eaves troughs, and sink holes. The larger breeding places are sluggish streams and swamps. Draining these is the most effective method of preventing mosquitoes from laying their eggs in such localities. When this is not possible, the surface of the water may be covered with kerosene, which kills the larvæ by preventing them from getting oxygen from the air. Frequent applications of oil greatly reduce the number of mosquitoes.

36. The House-fly. — Because of its filthy habits of breeding and living and because it comes to the dining room and kitchen crawling over the food, the house-fly has come to be recognized as a dangerous disease carrier.

37. Life History. — Each female lays from one hundred to one hundred and sixty eggs in stable filth or other refuse. The eggs hatch in a day or so into legless larvæ. In five to seven days, depending on the temperature and the food supply, the larvæ are full grown. They then pupate for another five to seven days. At the end of this time the adults emerge as mature flies ready to lay eggs for another generation. This continues until cold weather puts an end to their activities. Enough generations are produced every year so that a single female in the spring could have a million descendants by October if numerous enemies did not make this impossible.

38. Methods of Control. — Every one should support the "swat the fly" campaign and help reduce the number of flies. The few house-flies that survive the winter are responsible for the millions that swarm about in the summer. Their numbers may be reduced by several methods:

1. Begin early to kill the flies that are seen.
2. Remove all manure piles and make a general cleaning up of all refuse, thus destroying their breeding places.
3. Put fly traps on the covers of garbage cans to entrap all those that hatch as well as adults that go in to feed.
4. Keep many fly traps in operation in or about the house during the time of year that flies are active.
5. Poison those that do come in the house and keep fly paper ready for them at all times.

39. Tachina-fly. — This fly is beneficial to man. While it resembles the house-fly in appearance it has differences that may be clearly seen. It has long bristles on the abdomen and the bristle of the antenna is bare. The tachina-fly lays its eggs on such larvæ as tent caterpillars, army worms, and many other destructive caterpillars. After these eggs are hatched the tachina larvæ bore into the bodies of the army worms or tent caterpillars and there feed until they consume them. Many kinds of caterpillars are held in check by the activities of these tachina-flies.

40. Parasitism. — If a plant or an animal feeds on a living plant or animal, it is an example of parasitism. In the above, the tachina-fly is the parasite and the tent caterpillar is the host. The parasite feeds on the host. If it feeds on the outside of an animal, like the mosquito, it is called an external parasite. If it feeds on the inside of an animal, as in the case of the tachina-fly larva, it is called an internal parasite. Lice and fleas are external parasites. In some cases parasitism is helpful to man, as in the case of the tachina-fly; in other cases, it works harm to man, as in the case of the anopheles mosquito.

SUMMARY

The insects include a large number of animals, the smallest of which can be seen only through a microscope, while the largest, certain butterflies, measure nine inches across their

wings. Some insects are parasitic and lead dependent lives. Insects feeding on plants which we wish to eat are called harmful. Others, like the honey-bees and silkworms, which make products that we use, are beneficial. Insects such as ticks and lice, that injure our domestic animals, are harmful. Then there are the beautifully colored moths and butterflies whose larvæ never become numerous enough to do much damage; we say that they are beneficial because we get pleasure from their beauty.

The whole question of what is beneficial or harmful depends on the relation of the insect to man. Insects living on an uninhabited island could not be thus classified. In the earlier stages of our civilization, many insects now regarded as harmful were not so classified, because man had not learned to use the plants upon which they fed. The important relation which insects bear to disease has, in recent years, caused us to classify several insects as harmful which were not so considered earlier.

Insects, like man, are constantly undergoing a struggle to escape their enemies and to secure food and a place to live. It is interesting in this biological study to try to view ourselves in the same unprejudiced way in which we study the lower animals; it helps us to understand ourselves, and to go forth better equipped to wage our contest and win our fight.

QUESTIONS

Explain the difference between beneficial and injurious insects.

Which are some of our most beneficial insects? How do they help us?

How did they help to save the orange industry of California?

How do fruit growers spray their trees? Why?

What can you do to prevent harmful insects from spreading?

Describe the habits of ants and compare with honey-bees.

Name the common flies. What are their food habits?

Compare the life history of fly and mosquito.

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CHAPTER III

CRUSTACEANS AND RELATED FORMS

41. Crustaceans. — The *Crustaceans* (krŭs-tā′shŭns: Latin, *crusta,* crust) are so called because of their hard outer covering. They belong in the same group of animals as the insects. The body consists of a limited number of segments, each of which usually bears a pair of jointed appendages. The appendages are variously modified; some aid in swimming, others in securing food, and others are used in walking. The jointed appendage is the characteristic expressed in the technical name *Arthropoda* (är-thrŏp′o-da: Greek, *arthros,* joint; *pod,* root of *pous,* foot) given to the group to which all these animals belong.

Figure 48. — Crayfish, Showing Eggs.

42. Crayfish. — As a typical crustacean we have the common crayfish, or "crab" as it is known away from the seashore. The crayfish has nineteen pairs of appendages adapted to different kinds of work. It lives in fresh-water ponds and streams where there is sufficient lime for its use in building up its outside covering (exoskeleton).

The animal is divided into two regions, the *head-thorax* region and the *abdomen.* The segments of the abdomen are clearly defined, but those of the head-thorax are so fused that they cannot be made out.

43. Appendages. — The appendages of the head-thorax region are the most important to the animal. Certain of

these are fin-like and by their constant waving motion serve to carry food to the mouth. Others are elongated and serve for walking. One pair, the pincers, are used for seizing and holding food.

The last abdominal segment and the appendages next to the last are broad and form a tail fin (caudal fin).

Molting. — One of the interesting features in the study of the crayfish is the shedding of the external skeleton. Being covered by a firm exoskeleton it is necessary that this be removed occasionally, in order that the animal may grow. Molting, in the case of the crayfish, is a serious and dangerous operation, as it is followed by a period during which the crayfish is without means of offense or defense. The crayfish usually hides until a new exoskeleton is partially formed. In the molting process the covering of the eyes and part of the lining of the digestive tract, as well as the whole exoskeleton, are shed. The crayfish molts every year of its life and several times during the first year (Figure 49).

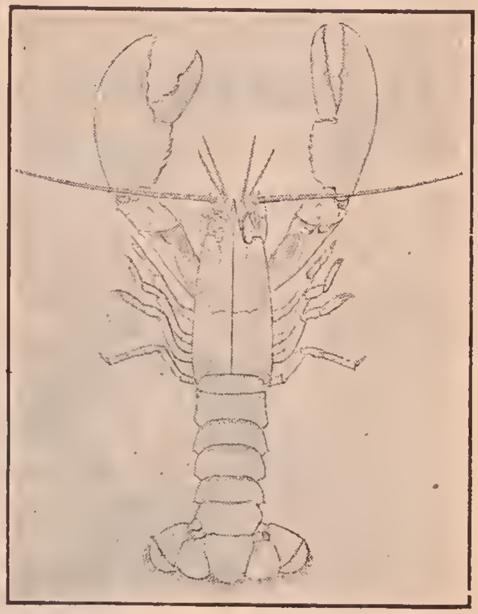

FIGURE 49. — MOLTED EXOSKELETON OF LOBSTER.

One can tell just what kind of an animal this is simply by studying this cast-off shell.

LABORATORY STUDY

Place several crayfish in jars or aquaria and observe their behavior. Fill out the following report:

Do they Move the Antennæ?	Do they Walk Forward?	Do they Walk Backward?	Do they Use Caudal Fin?	Do they Move Eyes?	What Organs Make a Current in Water?

Laboratory study on the appendages. Examine more fully than in the above and report the work of each pair of appendages. Compare one of the abdominal appendages with those used in walking and feeling. What is the work of the large pincers? How many fin-like appendages are found in the mouth region? Notice that one of the mouth appendages has a flat part that extends in front of the gills. This part of the appendage is called the gill scoop or bailer. Describe how the appendages show at least three useful adaptations in the life of the crayfish.

44. Food and Food-getting. — The food of the crayfish is both plant and animal, living and dead. One of the simple water plants, *Chara* (kā′ra), furnishes the crayfish with

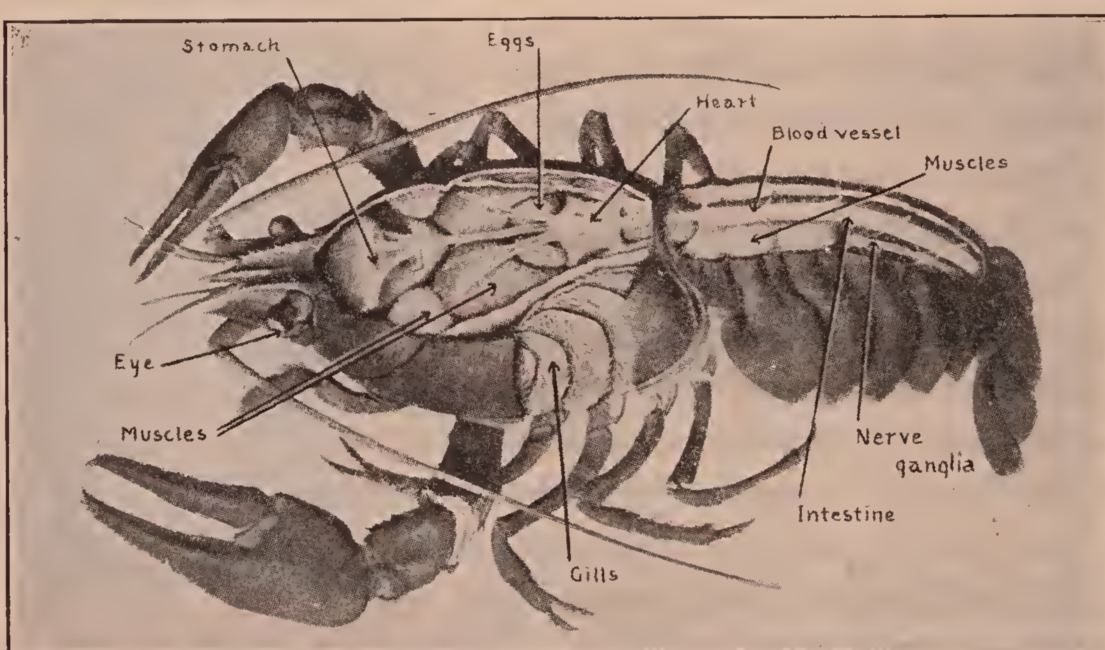

FIGURE 50. — ORGANS OF CRAYFISH.

Note that the gills are outside of the body. In the posterior part of the abdomen, the muscles have been removed to show the nerve ganglia which extend the entire length of the body.

lime for its skeletons. Shells of snails and their own shed skins also help to supply lime. Crayfish seize food with their pincers and move it towards the mouth. Small food particles are also carried towards the mouth by currents of water produced by the mouth parts and the abdominal appendages. Particles of food are torn loose by the teeth or mandibles.

45. Digestive System. — The mouth is just back of the teeth, and connects with the stomach by a short esophagus. The stomach is divided into front and back parts. The front part possesses a grinding structure known as the *gastric mill,* which serves to shred and crush the food and make it ready for digestion in the back part. The liver, or digestive gland, pours a fluid into the stomach, which

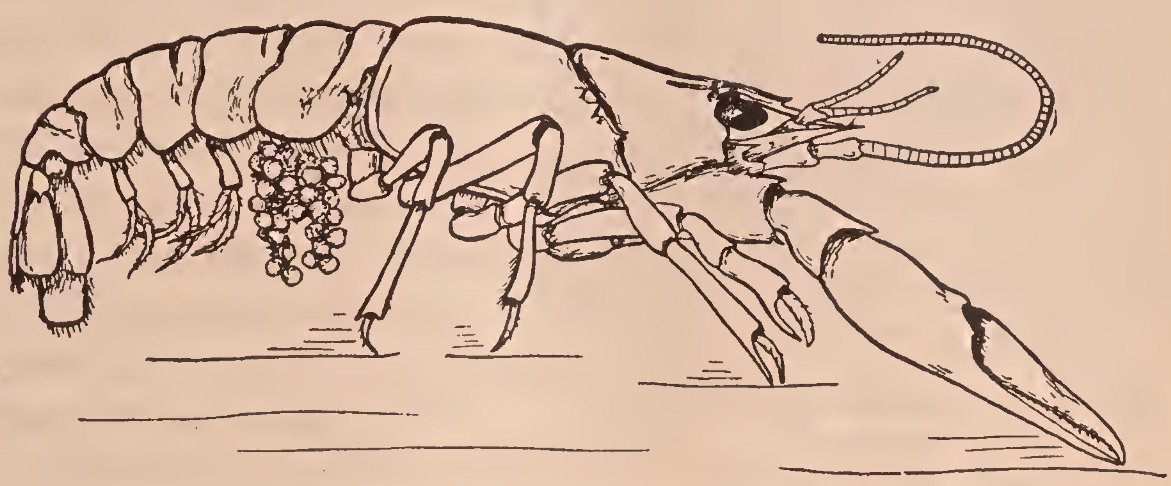

FIGURE 51. — CRAYFISH, SHOWING HOW THE EGGS ARE CARRIED.
This is the position that the animal takes when the eggs are being aërated; the rest of the time the abdomen is flexed as in Figure 48.

prepares the food for absorption by the walls of the stomach and intestines. The intestine begins at the back end of the stomach and extends to the last segment.

46. Respiration. — Crayfish obtain oxygen from the water by means of gills which are well covered by the overhanging skeleton of the head-thorax region, but are really outside of the body. Most of the gills are plume-like in shape and are attached to the appendages, but some of them are attached to the thorax. Water is made to circulate through the gill chamber by means of the gill scoop or bailer. The finely branched gill affords a large amount of surface for the absorption of oxygen.

47. Excretion. — The organs for excretion of waste are the *green glands* that are found at the base of the antennæ. Blood going to these glands loses some of the waste which

it has gained in its course through the body. The method of purification of the blood in these glands is much the same as in the kidneys of the higher animals.

48. Circulatory System. — The crayfish has a well-developed heart from which extend several arteries that carry blood to the various parts of the body. The blood returns to the heart through veins and through several irregular ducts called *sinuses* (sī′-nŭs-ĕs). As the blood flows through the body it loses oxygen and receives carbon dioxide. Fresh oxygen is absorbed by means of the gills, which, at the same time, pass off carbon dioxide from the blood into the water.

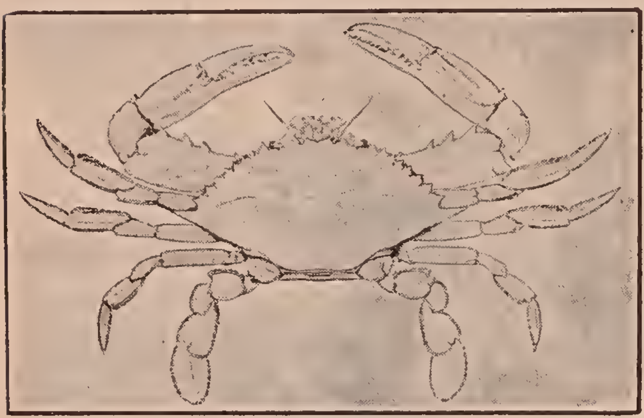

FIGURE 52. — SOFT-SHELL CRAB.
This is the common form sold in the markets.

49. The Nervous System. — In the crayfish this is made up of a brain, ventral nerve chain, and many nerves. The eyes are borne on a pair of short movable stalks. The special senses are well developed, and the sense of taste is keener than that of most lower animals.

50. Life History. — The sexes are distinct. The males may be distinguished from the females by the larger tubular appendages on the first and second segments of the abdomen. The eggs of the female are carried for some time by the appendages of the abdomen, where they pass through their early stages of development. The young crayfish is unlike the adult in form, and approaches

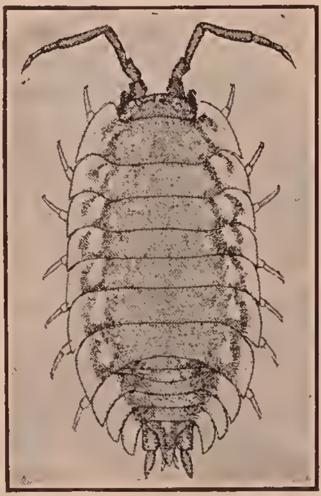

FIGURE 53. — PILL BUG.
Common under boards and sticks.

maturity only after passing through many changes.

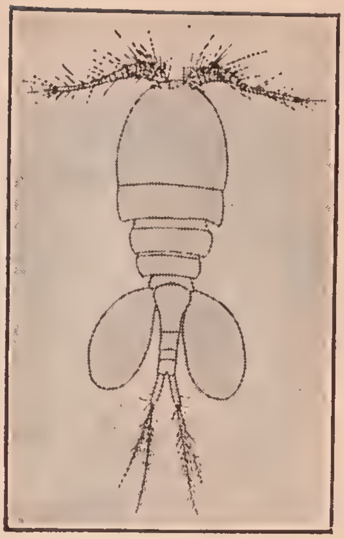

FIGURE 54. — CYCLOPS (much enlarged).

This is one of the commonest of the small freshwater animals. The two large sacs on the abdomen are the egg-sacs. It is the chief food of Hydra and the White-fish.

51. Other Crustaceans. — Shrimps, lobsters, and crabs are crustaceans of much economic importance, because of their food value. The trade in these animals amounts to millions of dollars each year. In order that these important food animals may not become exterminated by careless and excessive fishing, the state and national governments have attempted to control the numbers taken and have also established hatcheries in which the eggs are hatched and the young protected during the earliest stages of their development.

Crustaceans of less economic importance are the barnacles which cling to rocks, wharves, and ships; the hermit crabs that live in the shells of *mollusks* (mŏl′lŭsks); and the smaller fresh-water crustaceans such as the *Cyclops* (sī′klŏps), *Daphnia* (dăf′nĭ-a), and *Cypris* (sī′prĭs), which are barely visible to the unaided eye.

FIGURE 55. — DADDY-LONG-LEGS.

52. Arachnids. — The spiders, scorpions (skôr′pĭ-ŭns), ticks, and mites are arthropods that are grouped together under the name *Arachnida* (ȧ-răk′-nĭ-da: Greek, *arachne*, spider). The spiders and scorpions have eight walking appendages. The forward pincers of the scorpions are mouth-parts, and not walk-

FIGURE 56. — ONE OF OUR VERY COMMON SPIDERS.

ing appendages. The harvestman (*daddy-long-legs*) is a harmless arachnid which does good by destroying injurious insects. Spiders catch insects either by pouncing upon them or by entangling them in their webs. Scorpions sting severely, but the wound, although painful, is rarely fatal. Some ticks and mites are parasitic on man and beast.

53. Myriapods. — Another group of arthropods is the *Myriapoda* (mĭr-ĭ-ă′pō-dä: Greek, *myrioi*, ten thousand; *pous*, foot), a group which includes animals of many legs such as the centipedes (sĕn′tĭ-pēdz) and "thousand-legged worms." Centipedes are provided with poison glands, hence their bite is fatal to some of the smaller animals and painful to man. The thousand-legged worms are harmless.

FIGURE 57. — A TROPICAL SPIDER.

Note the eight legs characteristic of all spiders. The large size of its legs gives it strength to carry away prey.

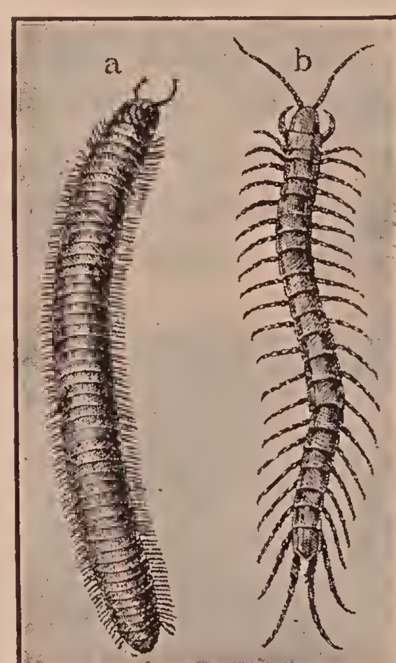

FIGURE 58. — *a*, THOUSAND-LEGGED WORM; *b*, CENTIPEDE.

Both these worm-like animals are members of the large class of Arthropoda and closely related to insects.

Note. Insects have been studied also in Chapters I and II, but it should be remembered that they are arthropods.

SUMMARY

An animal belongs to the arthropods if it has more than two pairs of appendages which have several joints in them. They also have an external skeleton which is shed at irregular intervals in order to allow the animal to increase in size. The body of the crayfish shows that part of the segments have fused to form the head-thorax region. The members of this group vary much in size and habits. Lobsters and crabs are valuable for food and for this reason should not be caught when they are small.

QUESTIONS

What kind of animals belong to the crustaceans? How can you distinguish one from a worm? From a hydroid? Explain why insects are arthropods. Which groups of arthropods are beneficial? Which are harmful? What do you mean when you say that an insect is beneficial or harmful?

REFERENCES

See Chapter II.

CHAPTER IV

FISHES

54. Vertebrates. — All the animals thus far studied are grouped together under the name of *Invertebrates*, because they have no backbone. We are now to study the *Vertebrates*, animals with a backbone, such as fishes, frogs, snakes, birds, and mammals.

The presence of a backbone in vertebrates is their most conspicuous characteristic. The formation of the backbone

FIGURE 59. — PERCH, AN IMPORTANT FOOD-FISH COMMON IN NEARLY ALL FRESHWATER PONDS.

is always preceded by the growth of an embryonic group of cells that do the work of a skeleton. This embryonic group of cells forms a structure which is called the *notochord* (nō′tō̍-kôrd: Greek, *notos*, back; *chorda*, cord). In all the true vertebrates (such as fishes, frogs, etc.), the notochord is gradually absorbed and the backbone takes its place, but between the vertebræ it remains as cushions. But in the

David Starr Jordan was born at Gainesville, N.Y., 1851, and is still living. He took his master's degree from Cornell in 1872, his medical degree from Indiana Medical College in 1875, and his doctor of philosophy degree from Butler University in 1878. Since then he has received the honorary degree of doctor of laws from four of the leading American Universities.

In addition to teaching biology for many years, he has written numerous technical and popular books on various phases of biology. From 1885 to 1913 he was President first of Indiana University and then of Leland Stanford University. During all this time he continued his scientific studies. He is one of the most eminent authorities on fishes in the United States. Dr. Jordan's life and attainments are striking examples of what an American boy can accomplish by his own efforts and individuality.

fish-like animal called *Amphioxus* (ăm-fĭ-ŏks′ŭs), the notochord persists and there is never a true backbone. The notochord is always found above the food tube and below the spinal cord.

Another characteristic common to all vertebrates is the presence of gill-slits. These are external openings on each side of the neck that in the fishes allow the water to pass

FIGURE 60. — SUNFISH OR PUMPKINSEED.
The one usually caught by the small boy fisherman.

over the gills. Such structures are of use only to aquatic animals, and yet all vertebrates have them at some time in their development.

In most vertebrates the skeleton is composed of bone. There are usually two pairs of appendages (legs, wings, or fins) attached to the body at the shoulder and hip. Here special bones join the limb to the body. The bones in the shoulder are known as the *pectoral* (pĕk′tō̍-ral) girdle ; while

those in the hip are termed the *pelvic* (pĕl′vĭk) girdle. In the snakes, only traces of legs are found (Figures 83, 88, and 89).

A further distinguishing feature of all vertebrates is the well-developed nervous system, with its large brain. The sense organs, eyes, ears, and the like, are also better developed than in any of the invertebrates.

Oxygen is obtained by external or internal gills in most aquatic animals and by lungs in all other vertebrates. In

FIGURE 61. — BROOK TROUT.

This is the most highly prized fish among fishermen. It is rapidly becoming extinct except where protected by law.

many vertebrates the skin is an active agent in the interchange of oxygen and carbon dioxide and particularly in those animals which have a thin, moist skin like frogs.

55. Fishes. — The fishes are vertebrates, that is, they have a notochord which, as they develop, gives place to a vertebral column. There are four large divisions of fishes: (1) the lampreys (lăm′prĭz) and relatives, (2) the sharks and relatives, (3) the bony fishes, and (4) the small group of fishes with lungs. The most important group in numbers and economic importance is the bony fishes. This group

includes the salmon (săm′ŭn), trout, bass, whitefish, pike, shad, menhaden (mĕn-ha′d′n), cod, mackerel, herring, sardine, etc. Typical bony fishes are the goldfish, perch, and sunfish (Figures 59 and 60).

56. External Parts of a Fish. — The external parts of a fish show a well-marked head attached directly to the trunk; a trunk region, the largest part of the body; and a tail region which is sometimes as long as the trunk.

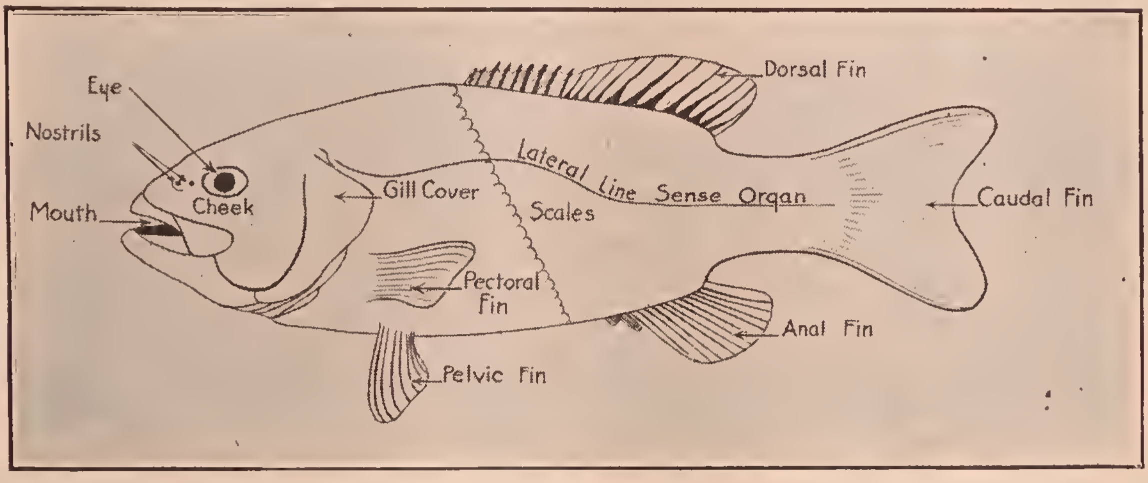

FIGURE 62. — DIAGRAM OF EXTERNAL PARTS OF A BASS.
These names are used in describing all fish.

In a bony fish the mouth is at the front end of the head. The jaw bones, bearing many small, needle-like teeth, are not firmly attached to the skull. The side of the head next to the trunk is protected by a piece of bone that covers the gills (gill cover or *operculum*, ō-pẽr′kū-lŭm).

The trunk bears a number of fins. Each fin is furnished with several bony fin-rays covered by a thin fold of skin. On the shoulder and hip regions of the trunk, the fins occur in pairs and are called the pectoral and pelvic fins. Several fins are found that are not in pairs. These are the median fins of the trunk.

FIGURE 63. — SCALES OF FISHES.

The caudal or posterior region of the

fish ends in a large median fin. The tail region is chiefly important in locomotion, but the fins also help in balancing and steering.

Scales cover the trunk and tail, each one overlapping like the shingles of a house. The skin is full of mucous glands that keep the fish covered with slime. Both the slime and the scales protect the fish (Figure 63).

LABORATORY STUDY

Study living fish, such as goldfish or perch. Place one or two in an aquarium and observe their behavior. Fill out the report below.

Number of Fins	Number of Paired Fins	Number of Unpaired Fins	Which are Used to			Do the Eyes Move?
			Advance?	Stop?	Balance?	

Note the shape and relative position of the head, trunk, and tail region. The gills are covered by a bony shield, the operculum. What is its size and how attached? Where are the eyes located? Do they move? Can the eyes be closed? How is the body covered? Of what use is this covering to the fish?

57. Locomotion. — The bodies of such fishes as are shown in Figures 59–61 are adapted to swimming. The tapering head offers but little resistance to the water and the general spindle-shape of the whole body enables it to move easily when completely surrounded by water. Notwithstanding that there are paired fins which are similarly placed to the paired legs of a frog or dog, these fins are not important in giving speed to the fish's movements. They act as brakes when the fish desires to stop, the brake being applied by simply straightening out these paired fins at right angles to the body. The median fins on the back and lower sur-

face of the body keep the fish from tipping over and are chiefly for balancing, the paired fins also assisting in this process. The tail of a fish is supplied with a large terminal fin. This fin and the tail of the rapidly swimming fish, which is often one third of the entire length of the body, is the chief

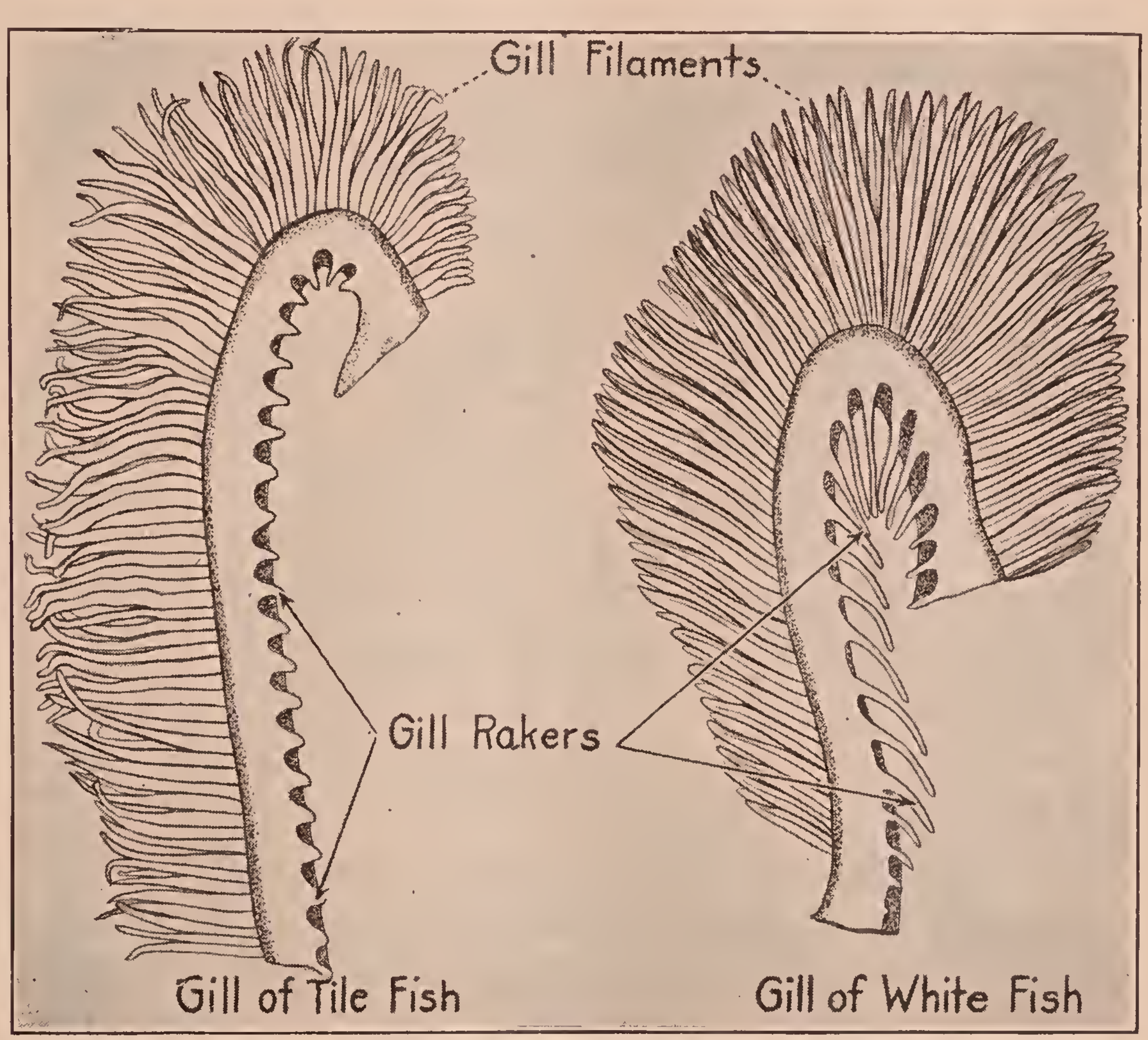

FIGURE 64. — THE GILL OF A FISH.

Blood vessels penetrate into the fine gill filaments where the waste carbon dioxide is given off into the water and oxygen taken into the blood. The gill rakers assist in capturing food.

organ of locomotion. Movement is produced by a rapid sidewise motion of the tail.

58. Food Taking. — Fishes eat insects, worms, crayfish, snails, and other fish. The teeth of fish serve to seize, tear, and hold food. None of the fish have teeth which are adapted to crushing or chewing the food, as is the case

among the higher vertebrates, like the dog, horse, and man.

Fishes which eat minute animals and plants have many sharp pointed projections on the inside of the gill arches which act as strainers and gather quantities of this small food as the water passes over the gills. These projections are called *gill-rakers* (Figure 64). Their development seems to vary in proportion as they are needed for service. Fishes that feed on crayfish and on small fish have no use for gill rakers or strainers and accordingly their gill rakers are undeveloped.

The food captured by the teeth of the fish or caught in the gill strainers passes at once into a short esophagus which expands into the thick-walled stomach. Here the various plants and animals that have been swallowed undergo partial digestion, the remainder of the process being completed in the intestines. The dissolved foods are absorbed through the walls of the stomach and intestines by osmosis and pass into the blood. The main parts of the digestive system and their adaptation to digestion are the same as in all the higher vertebrates.

59. **Respiration.** — Water is taken in through the mouth and passes out through two openings, one on each side of the neck. In each opening four or five gills are found. The gills are made up of numerous, small, very short, fleshy threads or filaments (Figure 64). Into each filament a blood vessel penetrates and here the blood throws off carbon dioxide and takes oxygen from the water by osmosis just as the blood of the crayfish does. The thin-walled gill filaments are adapted to respiration in the water. The water is drawn into the mouth and forced out over the gills in much the same way as water is pumped from a well. When a fish opens its mouth, the water rushes in. As the mouth is closed, the floor of the mouth and throat is raised slightly, pushing the water against the side of the neck and

through the gill opening. The mouth is thus emptied of water so that when it is opened again more water flows in.

60. Circulation. — The blood of fishes is carried in well-defined blood vessels and a heart of two chambers. The blood is sent from the heart to the gills, where it is purified of carbon dioxide and receives oxygen. It is then carried by means of arteries to other parts of the body, where the oxygen in turn is given up and carbon dioxide is received. The blood from the gills and other parts of the body is returned to the heart through veins. Because the blood of fishes is at a lower temperature than the blood of man and changes with the seasons, they are called cold-blooded animals.

61. Excretion. — The waste produced in all parts of the body as a result of the use of oxygen in the process of oxidation is in the form of a gas known as carbon dioxide. This gas is carried in the blood to the gills where it passes by osmosis through the thin walls of the gill filaments into the water. In addition to oxidation, there are other vital processes taking place in all the cells of the body of the fish. These vital processes produce waste substances that exist in the form of liquids which are gathered up by the small blood vessels and carried to the kidneys of the fish. Here these liquid wastes are extracted from the blood and are cast off from the body.

62. Nervous System. — The nervous system of a fish consists of a spinal cord and a well developed brain. There is no structure in the nervous system of a crayfish that can be compared to the brain of a fish. Many nerves connect the brain and spinal cord with all parts of the body and these nerves belong to the nervous system. Associated with a better development of the brain are special sense organs.

Special Senses. — The eye is well developed. It is globular and projecting, and it is believed to be near-sighted. The organs of smell are usually located in the nasal cavity.

In the bull-head, they are found in the feelers, on the head, and even in the skin of the tail. The ear is under the skin, and there is no external opening. As water conducts sound vibrations more readily than air, no device for gathering sound waves is necessary.

63. Reproduction. — The sexes of fish are distinct. At certain seasons many fish migrate upstream to lay their eggs (to "spawn"). Eggs are laid in large numbers by the females, and in the same locality sperm cells are discharged into the water by the males. The sperms unite

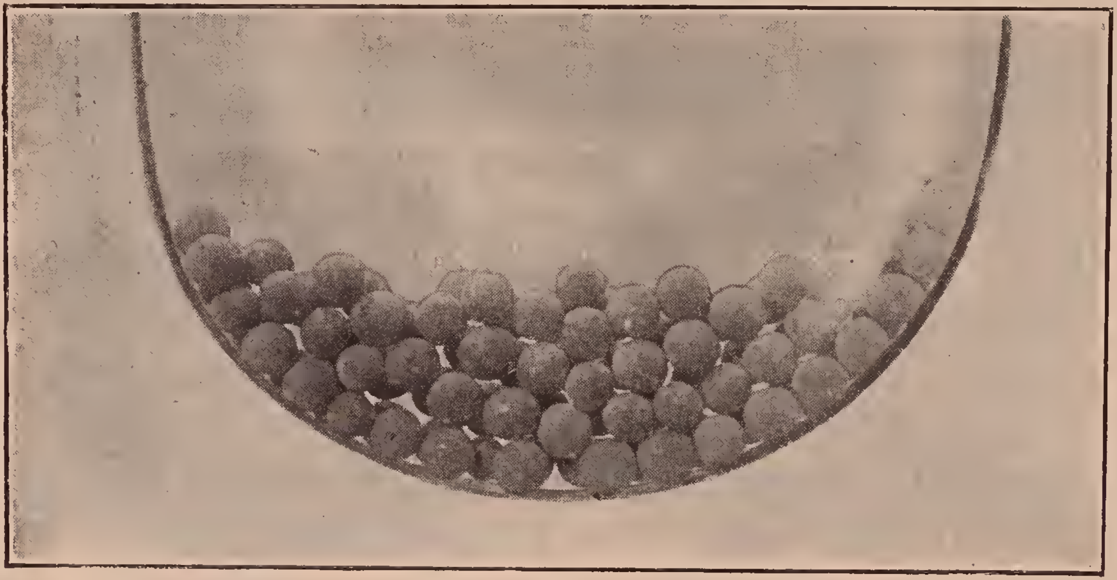

FIGURE 65. — EGGS OF THE LAND-LOCKED SALMON.

with the eggs. The fertilized eggs hatch after thirty or forty days, or longer, depending on the kind of fish and the temperature of the water. The yolk of the eggs is attached to the young fishes for many days after they are able to swim, and supplies all the food they need during this time. (Figure 66.)

The spawning habits of fish must be understood thoroughly if they are to be raised artificially, as is done in the many fish hatcheries. Most states have scientific game laws which protect the fish during their egg-laying period when they are easily caught and when the destruction of even a few fish means the loss of thousands of eggs.

Spawning habits vary greatly. Some fish, like the salmon, make long journeys from the sea to the head waters of rivers and streams to deposit their eggs. The Columbia River is famous for the number of salmon which spawn there. Other fish, like shad, go up a river only a short distance to lay their eggs. Many shad, for instance, go up the Hudson River in New York state. In the case of herring, the eggs are laid in the sea and float on the surface.

64. Life History of the Eel. — This well-known fish of the inland streams and lakes has had so many stories and myths in connection with its development that much effort has been made to learn the facts. Eels migrate downstream to the larger rivers and eventually to the ocean in the fall of the year. Here in the region of mud banks the females lay their eggs in great numbers and the sperm cells of the males fertilize them. In some cases the females lay as many as 10,000,000 eggs at one time. After the eggs are laid the adult eels remain in the ocean a few weeks and die. The young eels pass through the larval stage in about three weeks after the eggs start to hatch.

At the beginning of the second spring the young eels start on their trip back to fresh water. Great numbers of them may be seen in the spring at the foot of Niagara Falls where they are blocked by the great cataract. By crawling over stones and along the banks, young eels are able to get above ordinary falls in the streams and rivers.

The eel is a food fish. The commercial value of the eel is well known to fishermen. They are rich in oil and highly nutritious. Eels vary in weight from three and a half to six and a half pounds and often exceed three feet in length.

65. Fish Hatcheries. — In the natural state, many eggs are laid that never hatch because the sperm cells do not come in contact with them; and of the fishes that are hatched only a small proportion reach maturity. As it is a matter of great economic importance that fishes be

saved from extermination and their numbers largely increased, the governments of the world have established hatcheries where fish are raised in great numbers.

In these hatcheries the eggs are taken from the female and placed in a jar, and the mass of minute sperm cells or

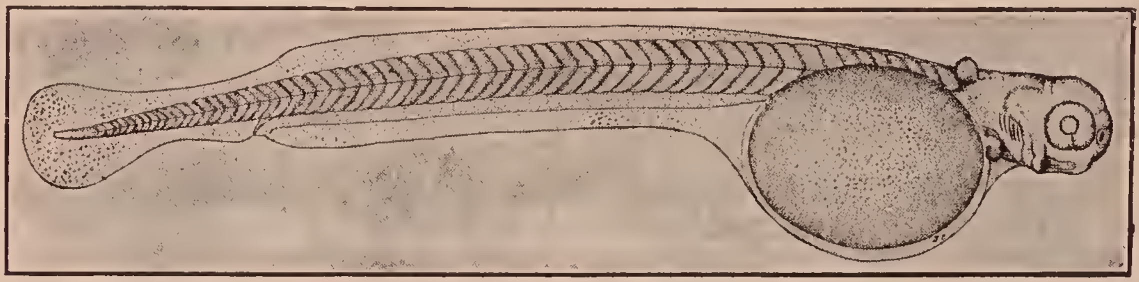

FIGURE 66.—YOUNG FISH JUST AT THE HATCHING STAGE.

The large mass under the neck is the yolk or food used by the young fish before it is able to capture its own food. Note that there are no fins and that the gills are not well developed.

"milt" is taken from the male and poured over the eggs, so that practically all the latter hatch. Then by giving the developing eggs protection, and the young fish sufficient and proper food, nearly all these eggs develop into active fish and the great loss that comes to the fish developing in

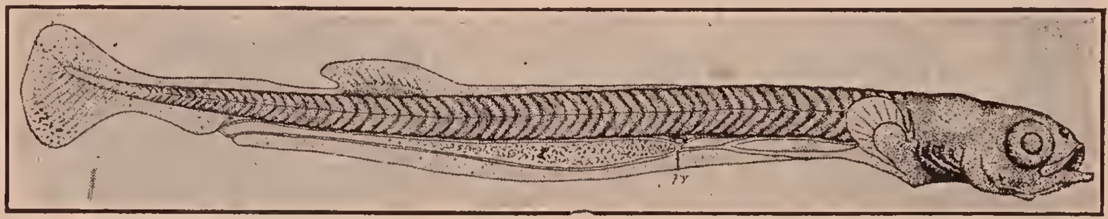

FIGURE 67.—YOUNG FISH SEVENTEEN DAYS AFTER HATCHING.

It has absorbed the large mass of food and the fins and gills are large enough to be used by the young fish which must capture its own food from now on.

their natural environment is prevented. When they are able to take care of themselves, these *fry*, as the young hatchery fish are called, are taken to natural feeding grounds. In New York State and most other states there are state hatcheries where such fish as shad, pike, lake trout, salmon, brook trout, and others are raised by millions.

The fish that are most useful as food are taken by hooks, nets, and seines, under certain restrictions. Those like brook trout which are caught as much for sport as for food can be taken only by a hook and line and in certain seasons, the season of the year depending upon the time of spawning. The brook trout spawns in August and September, while the rainbow trout does not spawn until February or March.

66. Possibilities of Food from Fish. — The United States, including Alaska, takes from the water about 2,000,000,000 pounds of fish, annually. Alaska produces about one fourth

FIGURE 68. — THE GRAYFISH BELONGS TO THE SHARK FAMILY.

It is very destructive in its food habits, eating the highly prized food-fish. How will the use of this fish for food help the fish industry?

of this total. The hatcheries of the United States have an output of 4,500,000,000 eggs, fry, and small fish.

Some of the fish have been caught in too great numbers so that they are growing less in number. Some are holding to their normal numbers and a few others are increasing. In the last class belongs the carp, kingfish, whiting, Pacific shad, and Pacific herring. Many edible fish are not eaten merely because people do not know about them or perhaps are prejudiced. Examples of such fish are sharks, toadfish, skates, grayfish, burbot, and menhaden.

The Carp. — This is one of our most abundant fishes in the lakes and inland streams. About 43,000,000 are sold

each year in this country. Since this species is hardy, easy to raise, easy to catch, and has high food value it is desirable that more of them be eaten.

The Grayfish. — The grayfish is found along the Atlantic coasts. Although its food value and flavor are equal to that of the tilefish and other food-fishes, it has not been marketable until recently. Unfortunately, when the fish was first named it was called "dogfish" from its biting habits. With that name people would not buy it. Now that it has a better name it is coming into use as a food-fish.

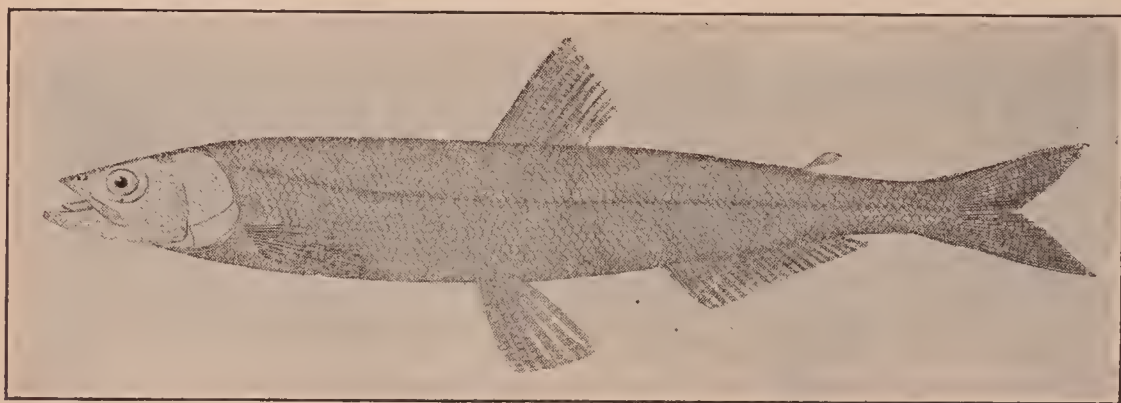

FIGURE 69. — THE WHITING OR EULACHON.
A food-fish recently placed on the market.

Its abundance enables fishermen to offer it for a relatively small price.

The Whiting. — This is another good food-fish that has only recently been in demand as a food. In 1898 less than 50,000 pounds were sold, while in 1908 more than 10,000,000 pounds were marketed. Since that time there has been a constant increase in the consumption of this fish. In England during 1913 about 70,000,000 pounds were sold at a price higher than haddock. The whiting occurs off the coast from New York northward. It can be bought fresh, canned, salted, and smoked.

67. Care of Young. — Some fish, like the sticklebacks, build nests of sticks and leaves in which the eggs are placed and guarded. Bass and sunfish make a circular depression

several feet in diameter near the shore and lay their eggs on these so-called " beds." These beds are guarded zealously by the males, who drive off or carry away crayfish and small fish which feed upon such eggs. In former times men sought for these " beds " and by dropping a baited hook caught the bass while defending their eggs. Fortunately this practice is now illegal. Generally, adult fish pay no attention to their young and in many cases they devour young of their own kind as quickly as fish of other sorts.

SUMMARY

The term *vertebrate* is given to all animals that have a backbone. All have gill slits, either while developing or as adults. Fish have scales and breathe by means of gills. Their eggs are usually laid in the water and receive no care from the parents. A few fish prepare a crude nest which they guard.

QUESTIONS

What are some of the structures that all chordates have?
Why is the word vertebrate used?
What are the common fishes near your home?
What ones are sought for food?
What is being done to keep up the supply of fish in your state?
What do fish eat?

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CHAPTER V

AMPHIBIANS

68. Amphibians. — Frogs and toads are the best known animals of this group; but here belong also the *Salamanders* (săl′ȧ-măn-dẽrs), frequently miscalled *lizards* (see page 99). The *amphibians* (ăm-fĭb′ĭ-ans: Greek, *amphi*, double; *bios*, life) are all small, the largest one found in America being a salamander (*Cryptobranchus*), which is rarely more than two feet long. This term amphibian is used to explain the habit which frogs, toads, and certain salamanders have of spending their larval (tadpole stage) life in the water and their adult life on land, or partly on land and partly in the water.

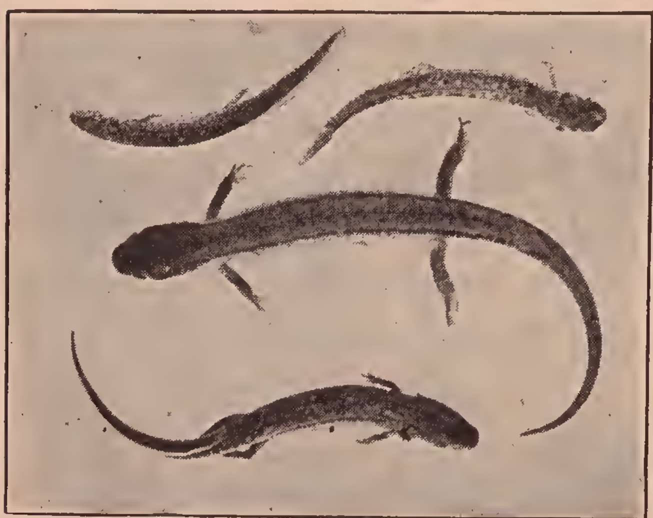

FIGURE 70. — SOME COMMON SALAMANDERS FOUND ON LAND.

LABORATORY STUDY

Place one or two frogs or toads in a small jar or box and observe the points mentioned in the report below.

DO THEY WINK?	CAN THEY PROTECT THEIR EYES?	HOW DO THEY GET AIR?	CAN THEY WALK? HOP?	HOW DO THEY SWIM?	HOW DO THEY CATCH A FLY?

69. Frogs. — There are several kinds of frogs, one of which, the leopard frog, is found generally distributed throughout the United States. It can be recognized by the presence, on the dorsal surface, of many brownish or greenish spots, edged with white, which help the frog to escape the notice of his enemies as he squats among the water weeds. These colors form rather definite bands on the hind legs, though there is much variation. The general form of the body, the shape of the head, and the long hind legs adapted for jumping are much the same in all frogs.

FIGURE 71. — LEOPARD FROG.

LABORATORY STUDY

Compare the general shape of fish and frog. How do the colors differ? Show how the legs and feet are adapted to the way the frog lives. Is the frog sensitive to touch in various parts of the body? Examine the eyes. Open the mouth and see that the frog can draw in its eyes. The ear membrane is on the side of the head back of the eyes. Pass a probe through the ear membrane of a dead frog and see where it comes out in the mouth. This is the opening of the Eustachian tube. How far can the living frog see? Notice the method of breathing. See the throat move up and down. Hold the frog under the water and gently rub its sides. It will usually croak. Thus we can prove that the frog is able to make the air travel from his lungs to his mouth and back again while under water.

70. Habitat. — Frogs are seldom found far from some pond or stream on the bank of which they are usually seen. When disturbed, they jump into the water, swim to the bottom, stir up the mud, and quietly come to rest a short distance from the place where they entered. As the nights in the fall grow cool, frogs make ready to spend the winter in a state of inactivity. During the warmer part of the day

they may be seen sunning themselves on a bank, but as soon as ice forms on the water they remain on the bottom or become buried in the mud. The lungs are emptied of air, the heart beats decrease, and all the usual life processes take place more slowly. This habit of passing the winter in a state of inactivity is known as *hibernation* (hī-bẽr-nā′shŭn). All the Amphibia, reptiles (Chapter VI, page 99), and several of the mammals hibernate during the winter.

Enemies. — As the frog's hind legs are considered a delicacy, man is the worst enemy of the frog. Next come the snakes, birds, and fish. The leech kills frogs by sucking their blood. Fish eat many of the tadpoles, and, strange to say, some water beetles eat tadpoles also.

71. Food. — Frogs are greedy creatures. They will eat almost any animal small enough to be swallowed, such as insects, worms, snails, tadpoles, and small frogs. These are caught alive and when in motion.

72. Respiration. — The oxygen of the air passes through both the skin and the lungs into the blood of the frog and the carbon dioxide of the blood is thrown off through these same two organs. The frog has large blood vessels close to the skin, especially along the back. These send many fine branches into the skin. This explains why the frog can "breathe" through its skin. When the frog remains under the water for a long time, as during the winter, all the oxygen used enters the blood through the skin. When the air is taken into the mouth, it is forced into the lungs by the muscles on the floor of the mouth. In a way, the air is swallowed into the lungs rather than breathed in as in the case of mammals. Experiments have been made which show that the frog can get oxygen in sufficient quantities to maintain life, even if it has not the use of its lungs. The frog thus possesses two organs of respiration, the skin and lungs.

73. Excretion. — This fundamental life process is performed in the frog as in all other vertebrates. Like the fish,

Jean Louis Rudolphe Agassiz was born in Switzerland, in 1807, and died at Cambridge, Massachusetts, in 1873. Agassiz introduced the laboratory method in zoölogy to students of America and trained many who have become prominent in biology. His motto, "Study nature not books," has been taken as a motto by thousands of students all over the world. He was the founder of the summer laboratory method of study now so common, the first such laboratory having been held at Penikese Island off the coast of Massachusetts He was Professor of Zoölogy and Geology at Harvard and Curator of the museum that now bears his name. His scientific contributions covered a wide range of subjects in zoölogy and geology.

it has a pair of kidneys that remove the wastes from the blood in the form of liquids; while the skin and lungs allow such wastes as the gas, carbon dioxide, to be discharged from the blood.

74. Irritability. — In all vertebrates this life process is limited to the nervous system, which includes brain, spinal cord, nerves, and sense organs as described in the discussion of the internal structure of the frog, page 88. Animals with definitely developed nervous organs and a specialized brain as in vertebrates are able to do more things than a worm, for example. The brain of a frog is really a very simple organ when compared with the brain of a dog. This is the main reason why a dog can be taught to do so many more things than a frog.

75. Reproduction. — The fundamental process of reproduction in the frog family is the same as in all other animals, but there is introduced the tadpole stage which makes the reproduction of the amphibians different from that of any other vertebrate.

76. Internal Organs. — In order that these several fundamental life processes may be better understood in a vertebrate, a knowledge of the structures involved is very important. This information will also help you to understand the several organs of man which are discussed in the third part of this book.

Digestive Organs. — The mouth is large. Short lips cover the short teeth in the edge of the upper jaw. The tongue, which has two fleshy horns at the back end, is attached by the front end to the floor of the mouth (Figure 72). The frog can throw its sticky tongue over the tip of the lower jaw and use the forked end to catch insects which are then carried into the back of the mouth. Two groups of little curved teeth in the roof of the mouth aid in preventing the escape of the prey. The food is swallowed whole. The esophagus (the tube connecting the mouth cavity and stomach) of the

frog can be stretched so that a comparatively large animal can be swallowed. There is no sharp limit between the esophagus and the stomach, which is a long spindle-shaped sac (Figure 72), larger than the rest of the digestive tube.

The small intestine begins at the back end of the stomach as a small tube which makes several turns, and finally enlarges into a region called the large intestine, the last part of which is termed the *cloaca* (clō-ā′cȧ) or common sewer.

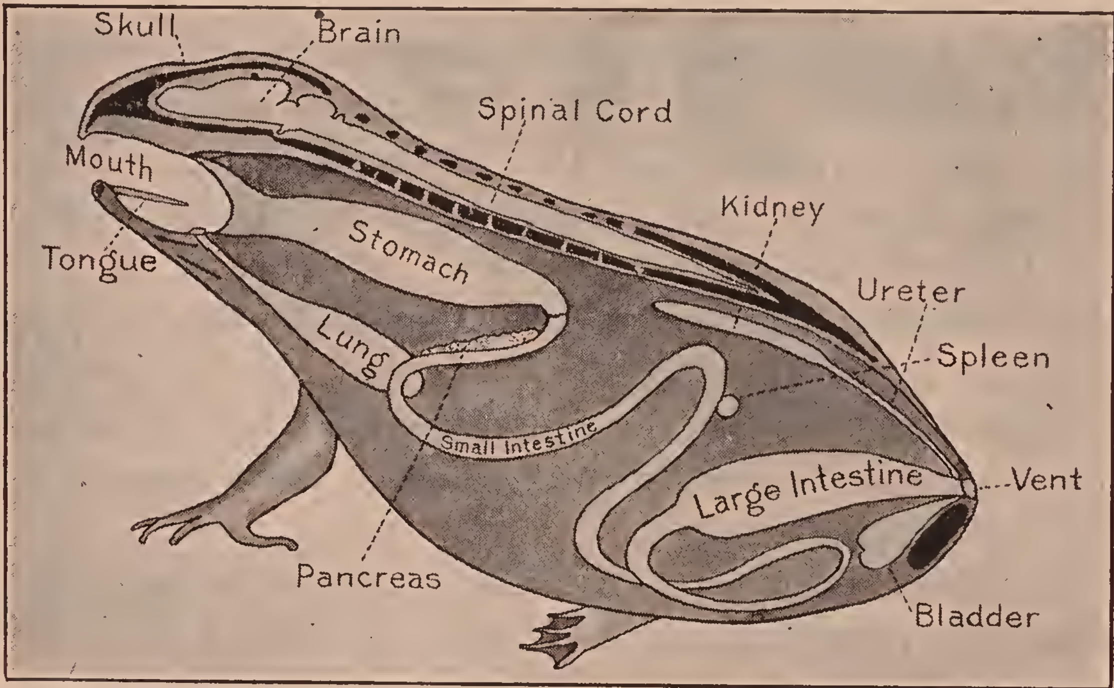

FIGURE 72. — DIAGRAM TO SHOW THE ORGANS OF THE FROG.
Note the relation of the nervous system to the body cavity. The large liver is omitted because it would cover the stomach and lungs if inserted.

Two glands of importance belong to the digestive organs — the liver and the pancreas. The liver is a large, dark-red, three-lobed organ that covers the ventral (lower) surface of the stomach. The pancreas is a whitish, small, irregularly shaped body attached between the stomach and the intestine. Both these glands drain into the intestine just beyond the stomach. The bile secreted by the liver is at first collected in a sac called the gall bladder.

All these parts of the alimentary canal are held in place by a thin membrane (the *mesentery*, mĕs′ĕn-tĕr-y), one edge

of which is attached to the dorsal wall along the line of the backbone and the other to the stomach and intestine. A small gland (the *spleen*) is found in this mesentery. The spleen has no duct connecting it with any other organ in the frog. Blood vessels run through the spleen, which scientists believe is important in making new blood corpuscles.

Lungs. — The lungs are hollow sacs that lie back of the stomach, one on each side. In the freshly killed animal, these can be filled with air by inserting a blow-pipe into the windpipe and blowing air into them. The empty lungs are about as large as the blunt end of a lead pencil.

Kidneys. — The kidneys are small red bodies lying close to the back. Each one is connected with the cloaca by a minute duct (ureter or urinogenital duct). The urinary bladder is attached to the cloaca (Figure 73).

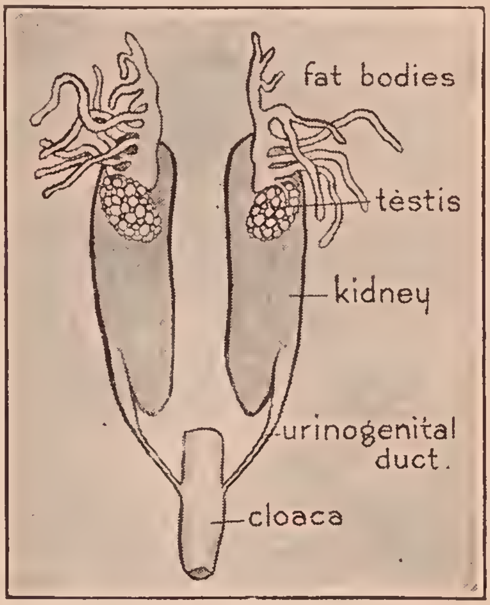

FIGURE 73.

Diagram to show the relations of the testes to the kidneys and the relation of the kidneys to the intestine (cloaca).

Reproduction. — The male frog has a pair of spermaries (spẽr′mȧ-rĭz), one attached to the front (anterior) end of each kidney (Figure 73). Each spermary (testis) is yellow in color. The sperms escape through the kidney. In the female frog ovaries, sometimes filled with eggs, are easily seen. A long, closely coiled pair of oviducts (ō′vĭ′dŭkts) opens in front near the forward end of the stomach and in the back into the cloaca. The eggs break through the wall of the ovary and enter the oviducts. As the eggs pass down through the oviducts, they are coated with a jelly-like covering that swells in the water. This jelly covering protects the eggs.

At the anterior end of each kidney in both the male and female frog is to be seen an irregular mass, the fat body, which contains stored energy that the frog uses as it begins to grow eggs or sperms in the early spring before there is plenty of food.

77. Nervous System. — The nervous system of the frog is more highly developed than that of the crayfish. It consists of a central part enclosed in the backbone and cranium (braincase). This central nervous system in all vertebrates is always found above the digestive tube, and is divided into the brain and the spinal cord, from which numerous nerves arise and extend to all parts of the body.

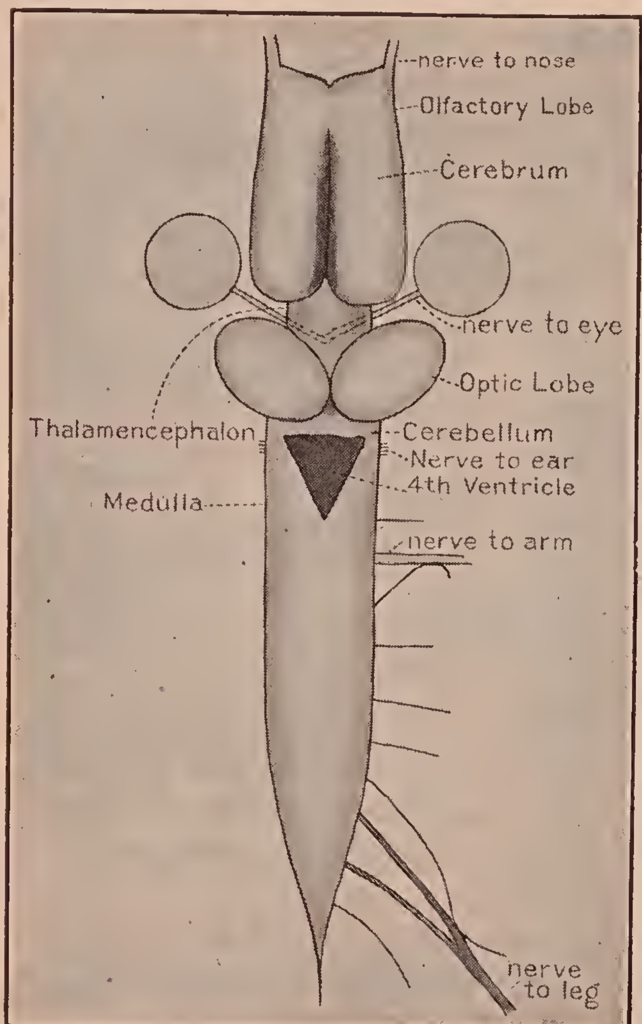

FIGURE 74. — CENTRAL NERVOUS SYSTEM OF FROG.

The parts of the brain are the same as in man and much easier to study. Beginning at the front (anterior) end of the brain the parts are as follows: (1) small *olfactory* (ŏl-făc′-tō̆-rȳ) lobes, which are not sharply marked off from the rest of the brain, and, as shown in Figure 74, connect with (2) the *cerebral* (sĕr′ē-bral) hemispheres, which are oval in outline. (3) A short mid-brain region, partly covered by the back part of the cerebral hemispheres, connects the front and back part of the brain. (4) Two large optic lobes, the widest part of the brain, are just back of

the mid-brain. (5) The *cerebellum* (sĕr-ē-bĕl′lŭm) of the amphibians is small and easily overlooked (Figure 74). The last region of the brain is the (6) *medulla* (mē-dŭl′lȧ), which is occupied by a large triangular cavity called the fourth ventricle.

The work which each of these regions of the brain does is not sharply defined. The olfactory lobes receive the smell stimuli. The cerebral hemispheres control muscular action. When the latter are removed, the frog loses all power to initiate any movement and will sit still in a dry, warm room for hours unless disturbed. This he never does when the cerebral region of the brain is uninjured. The mid-brain region is the passageway for all nerve-pathways that travel to and fro in the brain. The mid-brain and optic lobes explain to the frog the sight stimuli. In the frog, the cerebellum, which is poorly developed, is less important than in man. The medulla gives off more nerves than any other region of the brain. Here are found the nerves to the face, tongue, ear, heart, and lungs. While there is a great difference between the shape of the parts of the frog's brain and those of man, yet the work done by each region is of the same kind.

The brain joins the spinal cord, without any external sign to indicate where one begins and the other leaves off. A definite number (ten pairs) of nerves leaves the brain proper. These are devoted to the special senses of the head and to moving the muscles of the throat and head. The frog has ten other pairs of nerves joined to the spinal cord (Figure 74). In a long salamander there are twenty or thirty pairs of nerves on the spinal cord.

LABORATORY STUDY

In connection with the study of the frog, the following additional laboratory work should be done in order that the several organs of man which are discussed in Part III may be better understood. Frogs that

have been preserved in formalin can be easily dissected. Examine the digestive organs: first the mouth, then the esophagus, stomach, small and large intestine, and cloaca. For convenience, the liver will have to be removed. The pancreas can be seen as a small whitish structure in the loop between the stomach and the intestine. The spleen is a round red organ usually found near the large intestine.

A pair of narrow kidneys lies close to the back and is connected by ducts with the cloaca. The spermaries are found attached to each kidney near the front end and the sperm cells escape to the exterior by the kidney ducts. In the female frog the large ovaries occupy most of the

FIGURE 75. — FROG EGGS.

space of the body cavity. A pair of oviducts opens into the body cavity just back of the stomach. The eggs escape from the ovary into the body cavity.

The nervous system is enclosed in bone that is easily removed from the dorsal surface. The brain should be studied and the following divisions recognized: cerebral hemispheres ending in front in the olfactory lobes, which are not clearly marked. Just back of these the two large roundish optic lobes which are attached to the midbrain (*thalamencephalon*, thăl-a-mĕn-cĕph′ȧ-lŏn). The cerebellum is small, and the medulla passes into the spinal cord without any sharp dividing line.

78. Development. — Late in March and early in April the frogs gather in ponds to lay their eggs. The eggs are surrounded by a jelly-like substance which holds them together. As the eggs are being laid by the female frog, the male frog spreads a large number of sperm cells over the whole

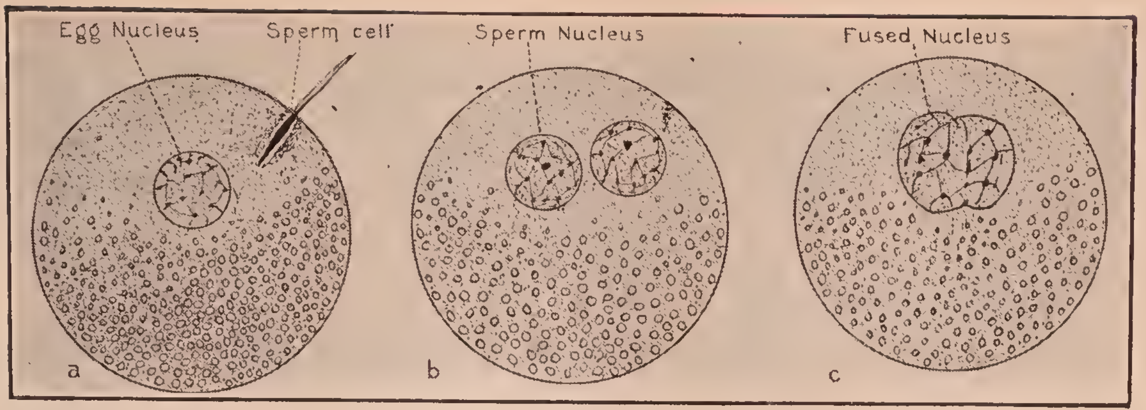

FIGURE 76. — DIAGRAM ILLUSTRATING FERTILIZATION IN FROG EGG.

a, The sperm cell is penetrating the cytoplasm of the egg; *b*, the head of the sperm cell has become transformed into a nucleus; *c*, the egg-nucleus and the nucleus derived from the sperm head fusing. This fusing is fertilization.

mass. These sperm cells make their way through the soft jelly and one of them must enter each egg or it cannot grow into a tadpole.

As soon as the sperm cell enters the egg (Figure 76), it begins to change from a solid, pointed body into a round nucleus which is so much like the nucleus already in the egg cell that none but experts in this study can tell which came from the sperm cell and which from the egg cell. These two nuclei come in contact and unite, leaving but one nucleus in the egg (Figure 76). This last change is fertilization, which is defined as the union of the contents of the egg and the sperm nucleus. After this union is completed the egg begins to divide into cells, as shown in Figure 77, and finally a tadpole is grown.

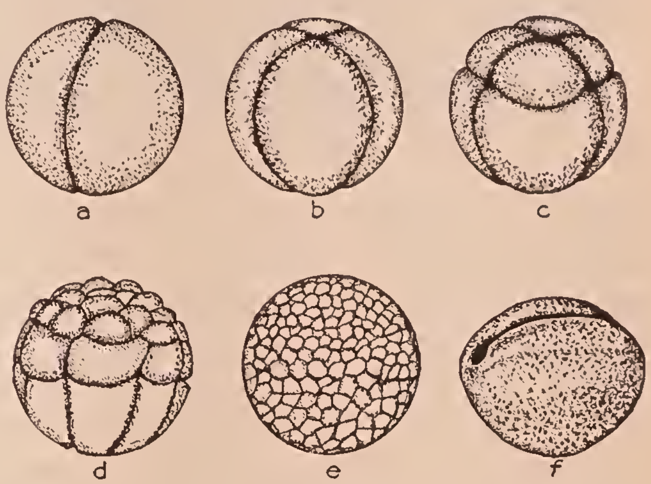

FIGURE 77. — DIVIDING EGG OF FROG.

After the egg has been fertilized as shown in Figure 76, the embryo begins to divide in a regular manner. *a*, Two-celled embryo; *b*, four-celled embryo; *c*, eight-celled embryo; *d*, thirty-two to forty-eight celled embryo; *e*, many celled stage; *f*, embryo beginning to form central nervous system.

As soon as the young tadpole hatches, it attaches itself to plants and lives for the first few days upon the food-yolk within its own body; the mouth forms, and horny jaws develop. Then the tadpole begins to feed upon minute plants and becomes dependent upon its own skill to get food and escape its enemies.

For a time the tadpole breathes through gills. Two sets are used. The first ones are on the outside of the body and last for only two or three days, when internal gills form in the throat and the tadpole breathes much like a fish.

FIGURE 78. — THE EMBRYO BECOMING A TADPOLE.

The Tadpole Becomes a Frog. — In the growth of the tadpole into a frog the hind legs appear first. Later the front ones begin to show and as they develop the tail is gradually absorbed. While these external changes are going on, there are many complicated internal changes taking place; internal gills are disappearing and lungs, nerves, blood vessels, and muscles are being formed to give the new legs life and action. The internal lungs take the place of the gills in the throat before the legs are fully grown and such tadpoles must rise to the surface to breathe air. Explain in Figure 79 which tadpoles breathe by lungs, and which by gills. This complicated way of growing into a frog is called *metamorphosis* and this term has the same general meaning as when used to describe the growth of insects (page 26).

The tadpoles of leopard frogs become small frogs in a

single summer, but the tadpoles of bullfrogs and green frogs require two seasons to complete their development. These latter tadpoles hibernate in the mud with adult frogs and toads.

79. Life History of the Toad. — In many respects the toad's life history is similar to that of the frog. The eggs

FIGURE 79. — TADPOLES.

The smallest tadpole, black, on the bottom of the aquarium jar is a toad tadpole about three months old. The other two tadpoles on the bottom are frog tadpoles about three months old; while the two tadpoles with legs are frogs. The larger is about one year old and the smaller three months old. This marked difference in size and growth is natural as each kind takes a different length of time to go through metamorphosis.

of the toad are laid in stagnant water in strings of a jellylike substance. (Figure 80.) The eggs hatch in from five to ten days into wriggling tadpoles, which feed on the microscopic plants that are found in water. They swim by means of their tails. Respiration is accomplished by means of the outside gills which allow the oxygen from the water to reach the blood and the carbon dioxide to enter the water. Later the inside gills take over the work of the outside gills and the

outside gills disappear. Still later, as lungs begin to develop, the tadpoles come to the surface for air so that for a time they are getting the oxygen both from the air and the water. (See Figure 79.)

About this time the hind legs begin to appear, the tail shortens and, soon after, the front feet may be seen. By the first of July the tail has entirely disappeared and the small toad begins to hop around on the bank, having the form, attitude, and habits of the toad as we see him in the garden. From the bank they begin to travel away from the water and scatter over the country in all directions. After

FIGURE 80. — DIFFERENT STAGES IN THE LIFE HISTORY OF THE TOAD.

a rain or during a shower, thousands of them are sometimes found hopping along a ravine or highway. Here they are run over by man and beast and fed upon by crows and other enemies. Of the hundreds that leave the pond but very few ever live to be a year old. Since toads feed on a great variety of harmful insects they are recognized as beneficial animals. Although slow moving, the toad is able to feed upon many flying insects which he strikes with his quick moving tongue, as they rest on plants or crawl over the ground.

The study of the changes through which the egg of the frog grows into a tadpole and then into a frog tells us much about the way frogs may have developed from fishes. The

tadpole breathes and eats like a fish; but as soon as lungs and legs are formed, it breathes and eats like a frog. This same study of the tadpole also illustrates how animals may gradually have come to live on land. In the early history of the earth there were hundreds of animals and plants which are no longer known to science. The skeletons, foot-prints, and whole bodies of many of these are preserved in the rocks. Such remains are called fossils.

If all the animals, or one of each kind, had been preserved in the rocks, it would be easy to investigate these earlier

FIGURE 81. — FOSSILS.

On the right a fossil leaf that grew on a sassafras tree; on the left a group of fossil animals that once were abundant but have become extinct.

animals and their relation to the living animals of the present. But in our information there are great gaps, which we are, however, gradually bridging. Apparently unrelated animals have resemblances, so that in time we may come to see that all animals are really related forms, varying only in complexity of structure. One thing that we must always keep in mind is that the plants and animals which live now are but a small fraction of those which have lived. The rocks

have preserved the remains of only a small part of the forms of the past. Many of the records of extinct animals and plants have been destroyed by decay and heat so that much that would be valuable in solving the question can never be found.

The study of the development of the frog also illustrates two other general subjects, *heredity* (hē-rĕd′ĭ-tȳ) and *environment* (ĕn-vī′rŭn-ment).

80. Heredity. — The tendency of all young animals to grow and live like their parents is called *heredity* and may be defined as the transmission of physical and mental traits from parent to offspring. There is no difficulty in recognizing the new frog as a certain kind of frog. The color markings on the skin are like those of the parents; it grows to about the same size; it eats the same kind of food, and lives in the same region.

Every species of living thing is able to produce new forms like itself, and heredity is always at work when new plants and animals are being produced. Heredity is best thought of as that quality of living matter which expresses itself in the growing plant and animal by making sure that it resembles its parents. Thus heredity determines that leaves of the right shape and size occur in the proper place or that fins in the fish or arms in the frog shall form in their normal position. The subject of heredity in its relation to man is presented in the chapter on Human Progress in this book.

A detailed statement of the laws of heredity is beyond the province of an elementary book, but it is now well established that certain traits of parent plants and animals are reproduced in their offspring in regular and definite amounts and proportions.

81. Environment. — This word is used in two ways. First, it refers to general surroundings such as temperature, moisture, and seasons, as they vary from year to year; and secondly, to immediate surroundings. The frog responds

to the first by hibernating in the winter; while the second phase of environment may be illustrated as follows: the tadpole can live only in water, and if the pond dries up before the frog stage is reached, the environment has been unsuited to the tadpole. This often happens when the eggs are laid in a temporary roadside pond which evaporates long before the tadpole becomes a frog. All such tadpoles die unless they are able to swim to some other body of water.

The birds that are able to fly avoid hibernating in the winter. They are able to adapt themselves to the change in the seasons without burying themselves in the mud as the frogs do.

Some of the birds do not migrate, but remain all winter in the North. They have become so well adapted to conditions that they are able to get their food where birds that migrate would starve.

FIGURE 82. — TREE FROG.

Note the disks at end of toes. Compare the environment of leopard frog and tree frog.

Man is the only animal that is able to live anywhere on the face of the earth under the most varied conditions. To realize this fully we have but to think of the different surroundings of the Eskimo, Indian, Bushman, and of ourselves.

Each animal and plant is directly dependent upon its environment for food and a home.

82. Economic Value of Amphibians. — The toad is the only member of the amphibian group that is of any great

value to man. It destroys many insects. Frogs eat a few but hardly enough to entitle them to high rank as beneficial animals. Their chief value is as food and as convenient forms for dissection in biology courses.

SUMMARY

The amphibians are an interesting group which illustrates how water animals may have become land animals. The frog has well-developed sense organs, legs modified for jumping, and feet for swimming. The skin is moist and helps to serve as an organ of respiration. The color markings and the habits of the frog serve to protect him from many of his enemies.

QUESTIONS

What animals belong to this class? How can you tell them from fish?

Where do the amphibians of your region live? How many kinds do you know?

See how many kinds of amphibian eggs you can find.

How long do tadpoles live before they become frogs?

What do frogs and toads eat?

What is fertilization? Metamorphosis? Evolution? Heredity? Environment?

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CHAPTER VI

REPTILES[1]

83. Reptiles. — Among the *Reptiles* (rĕp′tĭlz) are included lizards, snakes, alligators, turtles, and crocodiles. The *Reptilia* (Latin, *repo*, to crawl) are characterized by a

FIGURE 83. — RATTLESNAKE — POISONOUS.

Notice the triangular shape of the head and the small pit on each side of the nose. Compare with Figure 88.

covering of bony plates, or scales, in the skin, by the absence of gills in the adult stages, and by the presence of lungs.

84. Life History. — Unlike the amphibians, the reptiles hatch directly into their adult form, only much smaller.

[1] If desired, this chapter may be omitted without affecting the sequence in the book.

The young snake just out of the egg or the young alligator just hatched is recognized by its resemblance to its parents.

There is no metamorphosis, as in the frog. The reptiles lay their eggs in protected places and exhibit no parental care for the eggs or for the young. Some snakes hatch their young in the body of the parent and the offspring are born alive.

FIGURE 84. — COMMON SNAPPING TURTLE.

85. Turtles. — Turtles are easily recognized by their outer skeleton. This skeleton is unlike the skeleton of the starfish or crab, or of any other group of animals. The skeleton of the turtle, composed mostly of skin plates, is something like a box with a cover, the upper portion corresponding to the box itself, and the lower portion to the cover. The box does not fit closely all the way around, for there are places where the head, the tail, and the four legs stick out. When the turtle is disturbed, the legs, the head, and the tail are drawn inside, and the box is pulled down tightly by muscles to meet the cover.

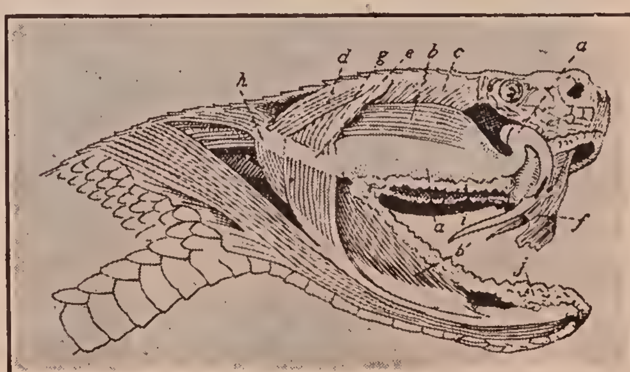

FIGURE 85. — HEAD OF A RATTLESNAKE. Dissected to show the poison gland, *a*, and its relation to the tooth. (Duvermoy.)

The term turtle is often applied to aquatic forms, and the term tortoise to those living on land. Sea turtles attain a length of six or eight feet and weigh sometimes as much as a thousand pounds. The flesh of the green turtle and of the *terrapin* (tĕr′rȧ-pĭn) is used for food.

6. **Lizards.** — There is a great variety of lizards. A common lizard is the *chameleon* (kȧ-mē′lē-ŭn), which has the power of changing the intensity of the color in the skin by moving the color material nearer the outer surface or drawing it away. The horned toad of the Western United States is a lizard with scales of varying length which give it a horny appearance. Horned toads, instead of laying eggs, have the eggs hatched while yet in the oviducts and the young horned toads are born alive. A poisonous lizard is the *Gila* (hē′lȧ) monster that occurs in New Mexico and Arizona. It has the poison glands in its lower jaw.

FIGURE 86. — HORNED TOAD, A LIZARD. Native in western part of United States and Mexico.

87. **Snakes.** — Snakes are legless vertebrates with long, cylindrical bodies covered with scales. They move by means of the scales (scutes) on the under side of the body. Most snakes lay eggs, but a few bring forth living young. Since snakes eat insects, frogs, mice, rats, and rabbits, they should be considered beneficial.

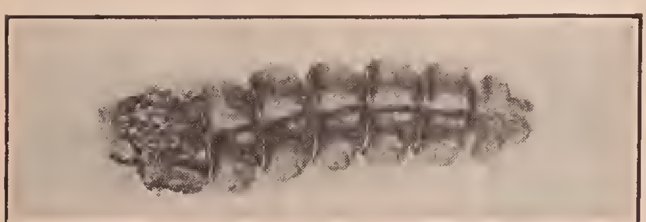

FIGURE 87. — RATTLES OF RATTLESNAKE.

Rattlesnakes[1] and copperheads are the most common poisonous snakes of our country. Their jaws are provided with fangs (Figure 85), by means of which a poison is injected into their prey.

[1] The two most common rattlesnakes are the mountain rattler and the *massasauge* (măs-sa-sä′ge)

Large snakes like the *black snake* or *blue racer* of the United States, the *boa constrictor* of South America, and the *python* (pī′thŏn) of Asia are constrictors. They are able to wind their bodies around their prey and to crush it to death. The most deadly snake in the world is the *cobra* (kō′brȧ) of India, where thousands of the natives die annually from its bite.

Snakes swallow their food whole, and as the teeth are used merely for holding their prey, they point backwards.

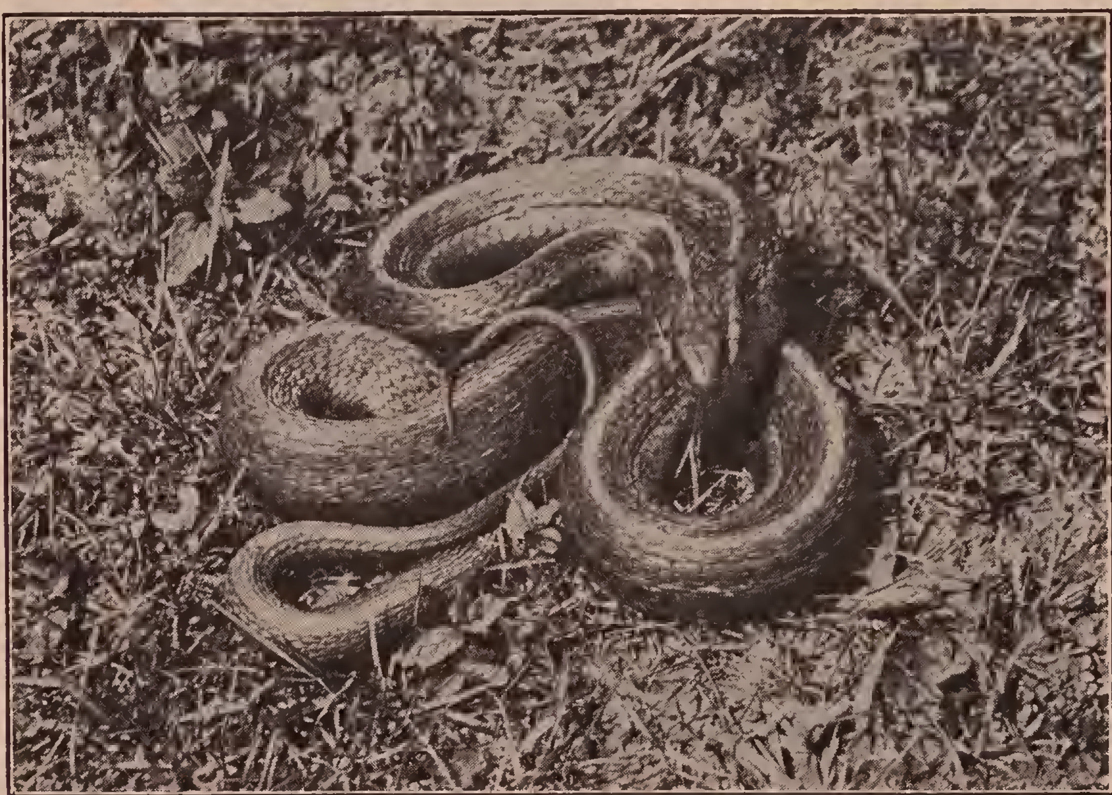

FIGURE 88. — GARTER SNAKE — HARMLESS.

Fear of Snakes. — In the case of many grown-up people there is a senseless fear of even the smallest snake. Small children are seldom afraid of snakes until some older person tells them that snakes are poisonous or that they will be bitten if they handle them. As a matter of fact the common snakes of the garden will not bite when carefully handled but rather seem to like to be handled. When one stops to think that snakes are cold-blooded while the hands are warm

it is not strange that they might come to enjoy the human hand. Some people are so frightened when they see a snake that a whole day of pleasure may be spoiled on this account.

Figure 89. — Bull Snake with Hen's Egg in Mouth.

It is unwise to put fear where there should be none and it is unwise to imagine that a harmless snake will bite. Fear takes a toll of our nervous energy and if we can learn to

Figure 90. — Bull Snake after Swallowing Egg.

banish senseless fear we have done something towards prolonging life and making our lives more efficient.

We need to learn about snakes enough at least to tell the

harmless ones from the poisonous ones. Also, we learn to overcome our fear of the little snakes. If one does not fear snakes and can handle them without minding, it is not wise to run after others with a snake in hand. People cannot be frightened out of their fears. A better way is to show

FIGURE 91. — ALLIGATOR'S NEST.
The heat of the decaying vegetation aids in hatching these eggs. Turtles lay their eggs in the sand.

them by handling a snake gently that it will not bite and that it enjoys being handled.

88. Alligators and Crocodiles. — Crocodiles are found in the Southern United States, South America, Africa, and India. Alligators are found in stagnant pools in the Southern States. Crocodiles resemble alligators but have narrower mouths.

89. Adaptations. — Reptiles are peculiarly adapted to their environment. Snakes that live in trees are some-

FIGURE 92. — EIGHT-FOOT FLORIDA ALLIGATOR.

times the color of leaves or bark. Some that are harmless are colored much like poisonous snakes. An adaptive feature of the crocodile is a fold of skin which shuts off the mouth from the throat and prevents water from entering the throat while the crocodile is drowning its prey. The old world chameleons have their feet modified for clasping

FIGURE 93. — POISONOUS LIZARDS — THE GILA MONSTER.
Native of Mexico.

branches. In the case of the turtles, those that live in the sea have paddle-like feet for swimming, while those that live partly on land and partly in the water have toes with webs. Lizards are almost always of about the same color as their surroundings.

SUMMARY

The reptiles always use lungs for breathing. They usually have scales or bony plates in the skin and have either two pairs of appendages (turtles, lizards, alligators, crocodiles) or none (snakes). It is important to learn to recognize poisonous reptiles, as their bite is dangerous.

LABORATORY QUESTIONS

From models or preserved specimens the difference between the harmful and harmless reptiles should be worked out. The living turtle can be studied easily. Its special skeleton is an illustration of protective adaptation. Notice how the nostrils of the aquatic turtle can be closed. How does this help the turtle?

QUESTIONS

What are the most common snakes in your vicinity? Are they poisonous? How can you tell? Where do they live? What do they eat? How many kinds of turtles do you know? Where do they live?

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CHAPTER VII

BIRDS

90. Bird Characteristics. — The front legs of birds are modified into wings. Among some birds, like the *penguins* (pēn′gwĭnz) of the Antarctic region, the wings are not used

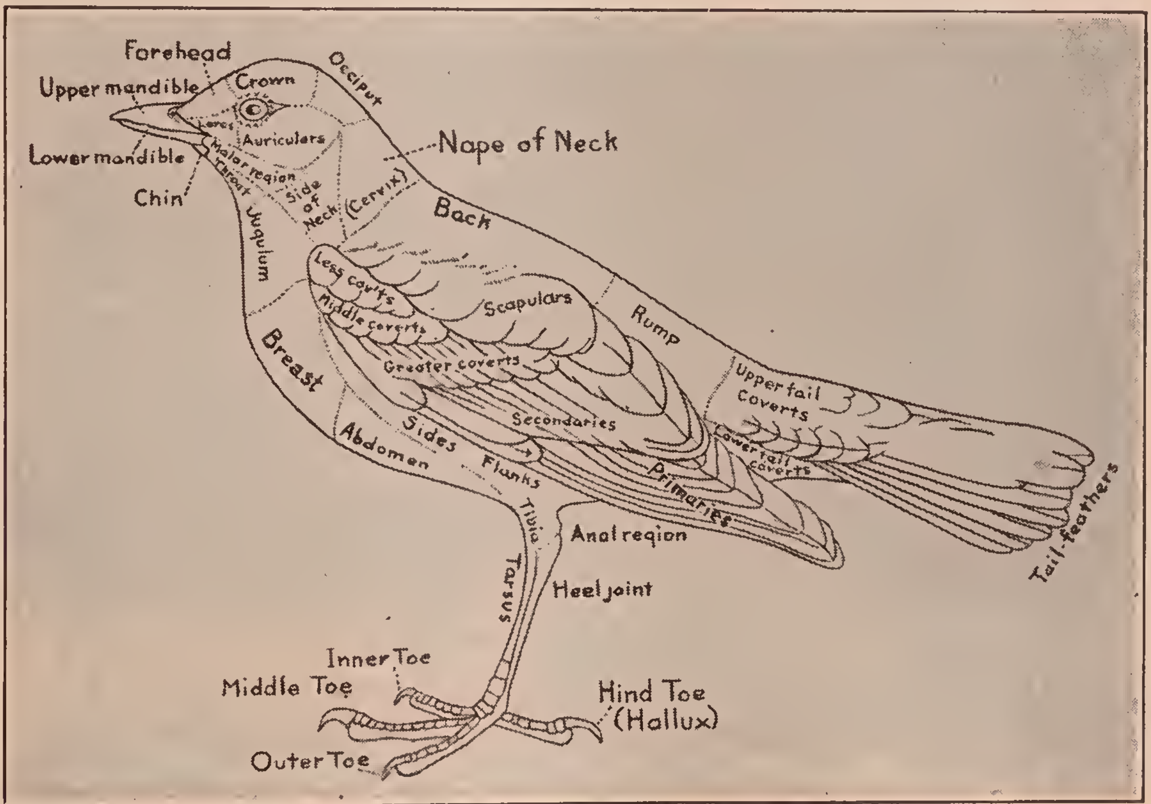

FIGURE 94. — REGIONS OF A BIRD.

The parts that you should learn when you begin the study of birds.

for flying but to assist in swimming. In others, like the eagles and condors, the expanse of the wings is sufficient to enable them to fly away with young lambs and large fish. Between the small wings of the penguin and the expanse of the wings of the eagle and condor there are many variations.

Bird wings are adapted to the needs of their owners.

Sailing birds, like the gulls, have long, slender wings, while ground birds, like the partridge and pheasant, have short wings capable of rapid, short flights. Those birds that make the most use of wings have them best developed. An example of underdevelopment, which has been increased by domestication, is seen in the domestic fowl, a ground bird,

FIGURE 95. — HERRING GULLS.
Note the different position and shape of the wings.

which makes little use of its flying powers, and is incapable of sustained flight.

The legs of birds also have many variations. In the case of the eagles, hawks, and owls there are powerful claws for seizing and holding prey, while ducks and geese have long and webbed toes, adapted to swimming. Seed-eating birds have weak claws which serve merely for perching. Chimney swifts, that spend most of their time in flight searching for food, have well developed wings, and feet used for clinging. Study Figures 96 and 97.

The beaks of birds show great variation and adaptation for defense and food-getting. Hawks, owls, and eagles have the upper jaw curved over, hooked, and adapted for tearing their food; herons and bitterns have the beak modified into a long, pointed weapon of offense and defense; grosbeaks (grōs′bēks) and finches have a short, stout beak for crushing seeds and other hard foods; while humming birds have a long, slender beak which in some kinds is curved so that they may reach the bottom of certain flowers. Study Figures 94, 99, 107, 109.

FIGURE 96. — ADULT SCREECH OWL. Showing the large eyes for night flying.

The birds show a number of other interesting adaptations which are of use to them. These are hollow bones, a keeled *sternum* (breastbone), and a high body temperature.

The skeleton of a bird shows a prominent ridge on the breastbone. This is the keel of the sternum, which serves as a place of attachment for the large wing muscles (Figure 98). The lungs of the bird are small, but air tubes extend into the bones, so that the body of the bird is relatively lighter than that of animals with solid bones.

Birds lead an active life, which means that they use a great deal of energy. This energy comes from the oxidation going on in the body. In birds, oxidation is more rapid than in other vertebrates, owing to the fact that they almost

completely change the air with each breathing movement and thus secure a greater supply of oxygen. The rapid oxidation requires that a large supply of food be digested and assimilated rapidly and it makes the normal body temperature of birds higher than that of other vertebrates.

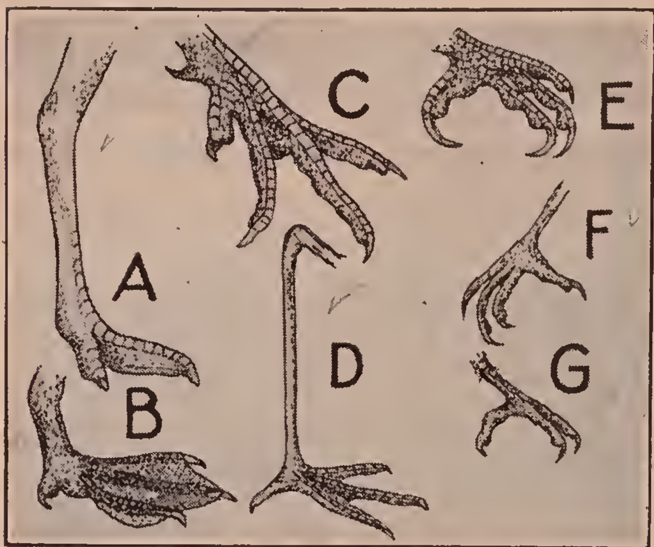

FIGURE 97. — BIRDS' FEET.

A, Ostrich's foot — adapted for running; B, duck's foot — adapted for swimming; *C*, hen's foot — adapted for scratching; *D*, plover's foot — adapted for wading; *E*. hawk's foot — adapted for tearing; *F*, crow's foot — adapted for perching; *G*, woodpecker's foot — adapted for climbing.

Plumage. — Birds are the only vertebrates having feathers and their plumage shows great variety in form and color. In some species there are certain colors which always predominate on the males, while the females have little color; in other species it is hard to distinguish between the sexes. The brilliantly colored males are supposed to attract the females at the mating season, while the dull colored females are inconspicuous and less likely to be attacked by enemies while hatching their eggs, or caring for their young. We may say, therefore, that they are protectively colored. The color of birds varies during the first two or three years of life.

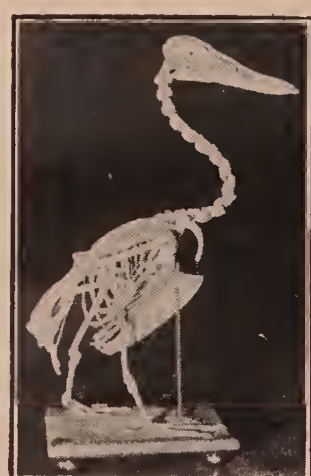

FIGURE 98. — SKELETON OF A MALLARD DUCK.

91. Classification. — Birds are usually divided into groups according to their structure. The shape and size of the beak and of the feet and wings are the characteristics most used in the general classification. This is illustrated by a single

John James Audubon (1780–1851), self-trained naturalist, supported his family by drawing portraits. His father was a French naval officer and his mother partly Spanish. He spent a few years in France where he gave his main energy to music, drawing, and natural history during the period when he was in training for the navy.

After his return to America about 1800, he became a wandering naturalist, ever seeking for new birds to study. As he went from place to place, he would pay for his lodgings or a new pair of shoes by making a portrait of some local celebrity or even the shoemaker himself.

His most famous work consists of one-thousand and sixty-five natural sized, colored figures of American birds, the publication of which alone took ten years and cost $100,000 Whenever you visit a large library, ask to be shown Audubon's Birds, the most noted book on American birds.

group of birds, the hawks, owls, and vultures, which are given the technical name of *Raptores* (răp-tō′rēz: Latin, *rapere*, to ravish), birds of prey. The bird books describe the Raptores as follows: toes four, three in front and one behind, except in the vultures; all toes armed with strong, sharp, curved *talons* (tăl′ŭnz); bill with a *cere* (sēr: Latin,

Figure 99. — Head of Young Eagle.
Notice the curved beak for tearing.

sera, wax) or covering of skin at its base through which the nostrils open, very stout and strong, the upper mandible tipped with a sharp pointed hook.

In addition to this classification by structure, which is essential for a careful study of birds, they are also classified by their habits. For example, birds are divided into four classes based on their migratory habits. Birds like the downy woodpecker and English sparrow are permanent residents throughout their range, that is, they can be found within given limits at any time of year, while bobolinks

and humming birds are summer residents, migrating southward at the end of the season. Birds like wild geese, fox sparrows, and the like, are transients, stopping along their migratory route for rest or food or to escape unfavorable weather; while such birds as the snowy owl, northern shrike, and evening grosbeak are winter visitants which migrate to us from the North when the cold becomes excessive and the food supply is diminished.

Figure 100. — Loggerhead Shrike.

This bird has the habit of hanging insects and small birds on the long thorns about its nest as it usually kills more than it can eat.

Birds are classified also by their nesting habits. Some birds, like the meadow lark and bobolink, nest in the open field, and their nests are made inconspicuous rather than inaccessible; other birds, like certain hawks and eagles, build their nests in tall trees, making them conspicuous, but inaccessible. Still others build like the oriole at the end of slender branches where they are out of reach of animals. Birds like the kingfisher, sand swallow, and puffins build their nests at the bottom of a burrow in the ground.

92. Nest Building. — Birds show great variation in nest building. Some build a large nest with materials loosely put together; others build small nests of neatly woven material, and some birds, like cowbirds, build no nest at all, but lay their eggs in the nests of other birds and

leave the work of caring for their young to the foster parents.

The number of eggs that birds lay in their nests varies from one to as many as thirty or forty. The time required to hatch the eggs varies from ten days to six weeks. Birds whose eggs hatch in ten days or two weeks are called *altricial* (ăl-trĭ′shal: Latin, *altrix*, nurse), for such young are hatched helpless, blind, and with little down. Eggs that hatch in from three to six weeks develop well-formed young, able to run around within ten to twelve hours after hatching. These are known as *præcocial* (pre-kō′shal: Latin, *prae*, before; *coquere*, ripen). Such birds have little need for a substantial nest and few of them build one. The robin is altricial, and the domestic fowl præcocial (Figures 102 and 103).

Figure 101. — The Robin.
Sometimes a permanent resident in the North.

93. Migration. — Because they are provided with wings and the power to fly long distances, birds are able to move from one region to another for the purpose of finding food and rearing young. The precise cause of migration is still unknown. Birds in general migrate to a warmer climate in the fall of the year and return to the cooler region in the springtime. In some cases birds cross the equator in migrating. For example, the bobolink nests in the Northern United States and passes the winter in South America, migrating a distance of over five thousand miles. In the case of the robin the migration is limited to a short flight to the South to some protected swamp provided with

water and food. A probable cause of migration is the failure of food supply as cold weather comes on in the fall.

94. Economic Importance of Birds. — The chief food of birds is insects, such as plant lice, larvæ of beetles, butterflies,

FIGURE 102. — YOUNG AND ADULT CHESTNUT-SIDED WARBLER.

moths, borers, etc. The chickadee, for example, feeds on plant lice as well as other foods; the downy woodpecker feeds on codling moths and borers; the nuthatches and brown creepers feed on insects and insect eggs that are hidden in crevices and under loose pieces of bark. Other useful birds are the song-sparrow, chipping-sparrow, robin, bluebird,

wren, blackbird, etc., which feed principally on insects that are found on or near the ground. The insects that fly, like mosquitoes, gnats, and house-flies, are eaten by swifts, swallows, night-hawks, kingbirds, and fly-catchers.

Among the hawks and owls is found a long list of beneficial birds, for the screech owl, red-tailed hawk, and the red-shouldered hawk are almost without exception valuable as

FIGURE 103. — EGGS OF THE WOODCOCK.

The nest is merely a depression in the leaves with no lining. The young leave the nest within a few hours after hatching, so that a nest to hold the young would be useless. Young that leave the nest soon after hatching are called præcocial.

destroyers of shrews, moles, mice, rats, weasels, and rabbits. The hawks that are partly harmful are the sharp-shinned hawk, Cooper's-hawk, and the marsh-hawk. All these help themselves to poultry and feed on small beneficial birds like the song-sparrow and bluebird.

The exact relation of birds to agriculture and the foods that they eat has been a subject of study by the Department of

FIGURE 104. — JUNCO.

A transient bird nesting in Canada and on the high hills and mountains of the Northern States. Beak is adapted for breaking small seeds.

Agriculture. Fisher reports the following results in his analysis of the stomach contents of 220 red-shouldered hawks: 3 contained poultry; 12 held 102 mice; 40, other mammals; 20, reptiles; 39, amphibians; 92, insects; and 16, spiders. A similar analysis of 133 stomachs of Cooper's-hawks shows the following: 34 of the stomachs contained poultry or game birds; 52, other birds; 11, mammals; 1, a frog; 3, lizards; 2, insects, while 39 were empty.

Aside from being of value in the destruction of insects, birds destroy waste matter and dead animals lying on the ground. The vultures and buzzards of the South and West eat dead animals. The gulls of the sea and lakes destroy refuse thrown upon the surface of the water. The eagle is also a scavenger, as it eats dead fish that float on the surface of the water, or small dead animals lying in the open on the land. Crows also eat dead fish.

FIGURE 105. — KINGBIRD.

A fly-catcher.

There is a group of birds that lives largely on seed, and such birds

destroy vast amounts of weed seeds. Among the seed eaters are the quail, grouse, pheasant, goldfinch, sparrow, bobolink, and meadow lark. A definite plan for bird study is suggested in the appendix. There are many facts which we should know about each bird which are more important than knowing its name.

FIGURE 106. — FEMALE BOBOLINK.

Notice the short, stout beak. This bird feeds on seeds during a part of the year. How would such a beak be an advantage?

95. Methods of Attracting Birds. — For the purpose of study and of appreciation, it is advantageous to bring the birds near the windows of a home where we may look upon them at odd times and study them at close range. There are several ways of getting the birds to come near a building. A common method is by feeding them. Foods such as suet, bread crumbs, hemp, canary seed, sunflower seeds, and raisins are attractive to birds. They should be so placed that cats cannot strike down the birds while they are feeding. Unless some care is exercised in selecting these feeding places, the birds will be lured into the claws of the ever waiting cat.

FIGURE 107. — KINGFISHER.

What advantage does a long sharp pointed beak give this bird? Note the short legs and small toes. Do kingfishers use their feet in catching fish?

Suet may be placed on the side of a tree trunk three or four feet from the ground in a bag or in a hole bored in the tree. Bird seed and crumbs may

be placed on the ground, but a better method is to put the seeds and crumbs in a box, with a cover a few inches above to keep out the snow. This box should be placed on a post or on the side of a tree trunk a few feet from the ground. Food placed on the ground is apt to be eaten by stray dogs or cats and in the winter time it will be buried by the snow.

FIGURE 108. — YOUNG CROWS IN NEST WAITING FOR FOOD.

Sunflower heads may be hung to the sides of a tree trunk or put on the end of a post.

During the winter the chickadee, whitebreasted nuthatch, downy woodpecker, hairy woodpecker, red-headed woodpecker, brown creeper, flicker, and many other birds may come to the suet. Juncos, tree-sparrows, house-sparrows, pheasants, crossbills, evening grosbeaks, song-sparrows, and prairie horned larks will come to the bird seed and crumbs.

Sunflower seeds will attract chickadees, house-sparrows, crossbills, goldfinches, and evening grosbeaks.

96. Nesting Boxes. — The putting up of nesting boxes in the yards is another way of attracting birds. In locating these nesting boxes it is essential to success that the place selected should be safe from cats. Cats will climb to the boxes if they can and strike the birds as they leave the nest. When birds are given a choice between several boxes put up in a small area, they seem to select those that afford them the best protection from their enemies. Boxes put up on the ends of posts and away from trees seem to be preferred to those put up in the trees. Poles and posts may be covered with tin or sheet iron to keep the cat from climbing them. The size of the opening and the inside space determine what birds will be likely to use the boxes. The table at the end of this chapter (see page 124) will give an idea of the size of the opening and the cavity and locations that are considered proper for some of our town birds.

FIGURE 109. — HAIRY WOODPECKER EATING SUET.

Note the long, stout beak, the toe nails, and the tail used as a prop. How are each of these useful to the woodpecker?

97. Bird Baths. — During the dry weather of July and August, the supply of water is greatly reduced. Sometimes the water that is available is in a place where the birds have no chance of escaping a cat that is lying in wait for them. A shallow plate of water placed on a stump or post in the shade is frequently used by the birds. Sometimes a dozen or more

FIGURE 110. — MALE AND FEMALE COWBIRDS.

Notice the difference in shade of the two birds. The female at the right is gray. What advantage would a dull color be to her while she was in the nest of another bird?

kinds of birds will come to these drinking places. At one such bath the following birds came during one summer: robin, oriole, catbird, yellow warbler, song-sparrow, pewee (to catch insects at the water), red-headed woodpecker, black-throated blue warbler, and goldfinch. Birds will bathe in the drinking fountains if they are shallow enough to allow them to wade.

98. Adaptations of Birds for Winter. — Birds have several ways of meeting the unfavorable conditions of winter. The great majority migrate to a more favorable climate, the bluebirds going to the Southern States, while the bobolinks migrate to South America, some of them as far as Argentina. The red-headed woodpecker lays up beechnuts and acorns in the fall and feeds on them during the winter. The goldfinches that are common about our homes in the early fall gather in flocks and frequent swamps and heavy timbered regions, feeding on fruits that still cling to the trees. The ruffed grouse has a fringe of tissue that grows on its toes

which act as snow shoes, enabling it to run over the snow without sinking in. This adaptation disappears in the spring when the need for it no longer exists. In the case of the ptarmigan of the Western States, the winter plumage is white but the summer plumage is brown and gray. The white plumage matches the snow, making it more difficult for enemies to find the bird, and the white plumage is warmer than any other color.

99. Adaptations of Birds for Food-getting. — These adaptations are chiefly seen in the beak and the feet. The hooked beak of the eagle is an adaptation for seizing and tearing. The long beak of the kingfisher is an adaptation for spearing fish. The beak of the cowbird is short and thick for breaking up seeds. The hairy woodpecker has a chisel-like beak for cutting holes in trees, where it finds its food. The woodcock has a flexible beak for probing in the mud (Figure 111).

The strong feet and curled claws of the hawk are adaptations for seizing and holding its prey. The long toes of the gallinules allow them to walk over floating leaves in search of food. The woodpeckers have two toes in front and two behind which give them a firm hold on the bark while they are driving holes in the tree. The loons have webbed toes that they may swim under water and pursue fish. The domestic fowl has large strong nails to assist in scratching for its food. The beaks and claws of most birds will be found fitted for the kind of work that the birds must do, either to procure food or to protect themselves.

100. Public Museums. — As man came to occupy the land, the forests were cleared away and the ground used to produce food for man and domestic animals. This tended to drive the wild life, native to such regions, into the mountain fastnesses where they were free to live. This resulted in many of them becoming extinct even when they were of great use to man. The bison and brook-trout are two good examples (Figure 61). The expense of collect-

FIGURE 111.—WOODCOCK ON NEST (incubating).

This is an example of protective coloration. The pattern of the sitting bird blends with the surroundings so that it is difficult to see the bird as long as she remains quiet. Note that this bird can see directly behind her without turning her head. The eyes are placed well back in the head. This is an adaptive feature and serves to protect her.

ing and properly housing the preserved skins and skeletons of such animals is beyond the means of most people. The public museum is the proper place for all such collections, as a few specimens which can be seen by all is much better than many specimens in private collections. The men in charge of museums never indulge in useless slaughter as is so frequently done by hunters.

Every student in such a course as this should plan to visit the public museum or zoölogical park or botanical garden in his city as the different parts of the course are taken up. Pictures and drawings can never take the place of seeing the actual specimens. Going to the museum is like going into the laboratory for first-hand study of the facts. It is studying nature as she is.

FIGURE 112. — NEST OF THE YELLOW WARBLER IN WHICH A COWBIRD EGG HAS BEEN LAID.

The warbler first built the nest at the bottom. When this nest received a cowbird egg, a second nest was built on top. Again it was visited by a cowbird and a third nest was made. When the cowbird egg hatches, the young is larger and grows faster than the small warblers. After a time this large bird crowds the small warblers out of the nest and they die. What should you do when you find an egg of a cowbird in a warbler's nest? From Zoölogical Museum, University of Minnesota.

101. Public Preserves. — During the past few years, large areas have been set aside where the wild life, especially the birds, can live unmolested. Many bird refuges are being established over the country where no one is allowed to hunt birds. In these refuges (or preserves) nesting boxes are put out for the birds to use, drinking fountains are kept running during the dry seasons, and food plants for birds are set out or the seed sown. Many farmers post their lands in order to save the game birds and game animals that are in danger of being exterminated by too much hunting.

SUMMARY

Because of their feathers birds can easily be recognized. The fore-limbs are adapted for flying, and as such vary in size. The feet are modified for swimming, running, perching, or tearing; while the jaws are large and powerful, or small and weak, depending on the habits of the bird. The classification of birds according to their habits makes it easy to learn about them. Birds are of great economic importance in destroying many kinds of insects that are detrimental to man. This explains why they must be protected by law.

TABLE — SIZE OF NESTING BOXES

Bird	Diameter of Opening	Size of Cavity	Location
Chickadee	$1\frac{1}{8}''$	4×4	In protected spots
House wren	$1\frac{1}{8}''$	4×4	Trees and arbors
Nuthatch	$1\frac{1}{4}''$	5×6	On buildings or trees
Bluebird	$1\frac{1}{4}''$	5×6	On buildings or trees
Tree-swallows	$1\frac{1}{4}''$	5×6	In trees near ponds
Red-headed woodpecker	$2\frac{1}{2}''$	6×7	On posts or trees
Flicker	$3''$	6×8	On posts or trees
Wood-duck	$6''$	10×18	Trees or stumps

QUESTIONS

How many birds do you know? What do they eat? Do they remain all winter? Which ones migrate? Where do they nest? What time of year do the young leave the nest? Why are the birds beneficial?

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CHAPTER VIII

MAMMALS

102. The Mammals are the most highly developed of the vertebrates. They are warm blooded (the body temperature remaining the same in winter and summer), breathe by means of lungs, and are provided with milk glands to nourish their young. Most mammals

FIGURE 113. — SKELETON OF A DOG.

FIGURE 114. — COYOTE.

These animals do many thousand dollars of damage annually to the breeders of cattle and sheep in the Western States.

are covered with hair. A muscular wall (diaphragm) subdivides the body cavity into two parts. The anterior part contains the heart and lungs, and the posterior part contains the stomach, intestines, liver, and other organs. At birth the young look like the parents.

Most mammals have two pairs of limbs. The fore limbs may be variously modified for different uses, as for walking in animals like the horse, for climbing and for food-

getting in the squirrel, for burrowing and locomotion in the moles, for flying in the bats, and for swimming in the seals. In all fore-limbs of mammals, even in those as different as the leg of the squirrel, the flipper of the seal, and the wing of the bat, the arrangement of the bones is the same. The hind-legs of mammals do not show so much variation as the fore-limbs. But in some cases, as in the whale, the hind-legs have almost disappeared through disuse, and there is no external evidence of them. Some animals, like the bears, walk on the soles of their feet, and some, like the cats and the dogs, walk on all their toes. In some mammals there is a variation in the number of the toes. For example, the cow walks on two toes and the horse on one toe, the hoof being a modified toe nail. In such cases the other toes are entirely lacking or rudimentary (not perfectly developed).

FIGURE 115. — FLYING SQUIRREL.

The skin is stretched between the fore- and hind-legs and acts like a parachute. Does the animal really fly?

103. The Horse. — The horse is interesting because it has been associated with man since the pre-historic period known as the Stone Age. It has been suggested that man "first hunted horses for food, then drove them, and finally used them for riding and as beasts of burden." The fine animals which we see to-day have gradually developed through this

FIGURE 116. — BROWN BAT.

Notice how the wings of the bat are formed. Membranes are stretched between the bones of the fingers, between the arms and legs, and between the legs and tail. This entire structure is known as the wing of the bat. How does it differ from the wing of a bird? What other special adaptations do you see?

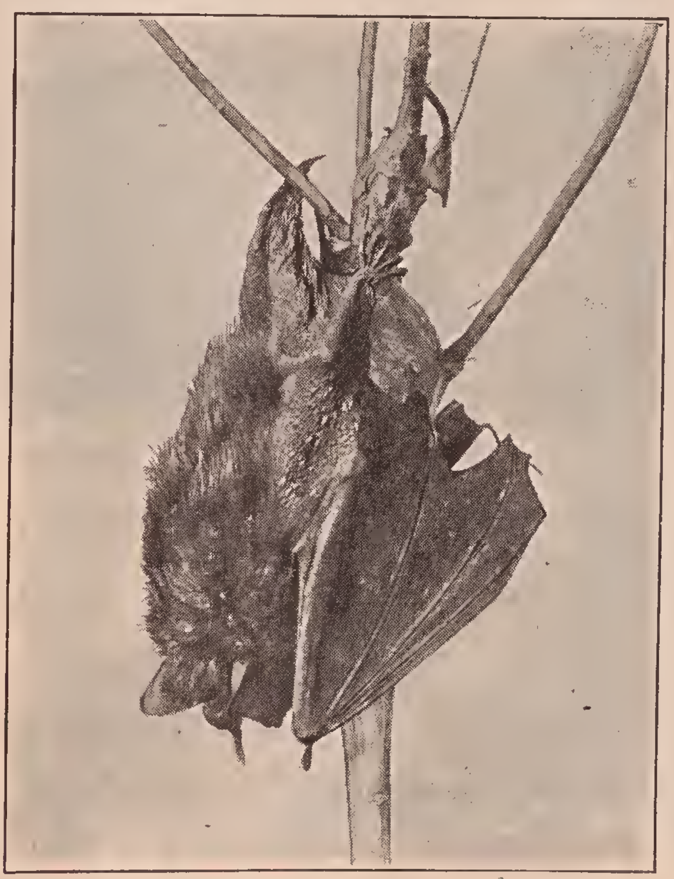

FIGURE 117. — BAT HIBERNATING.

During the winter sleep the bat hangs suspended in some cave.

long time from a small animal about the size of a fox terrier. The earliest remains of the feet of the ancient horse show that it had four toes and the remains of a fifth in the front foot, while the hind foot had three toes and the remains of a fourth. The horse and the deer, which also has many

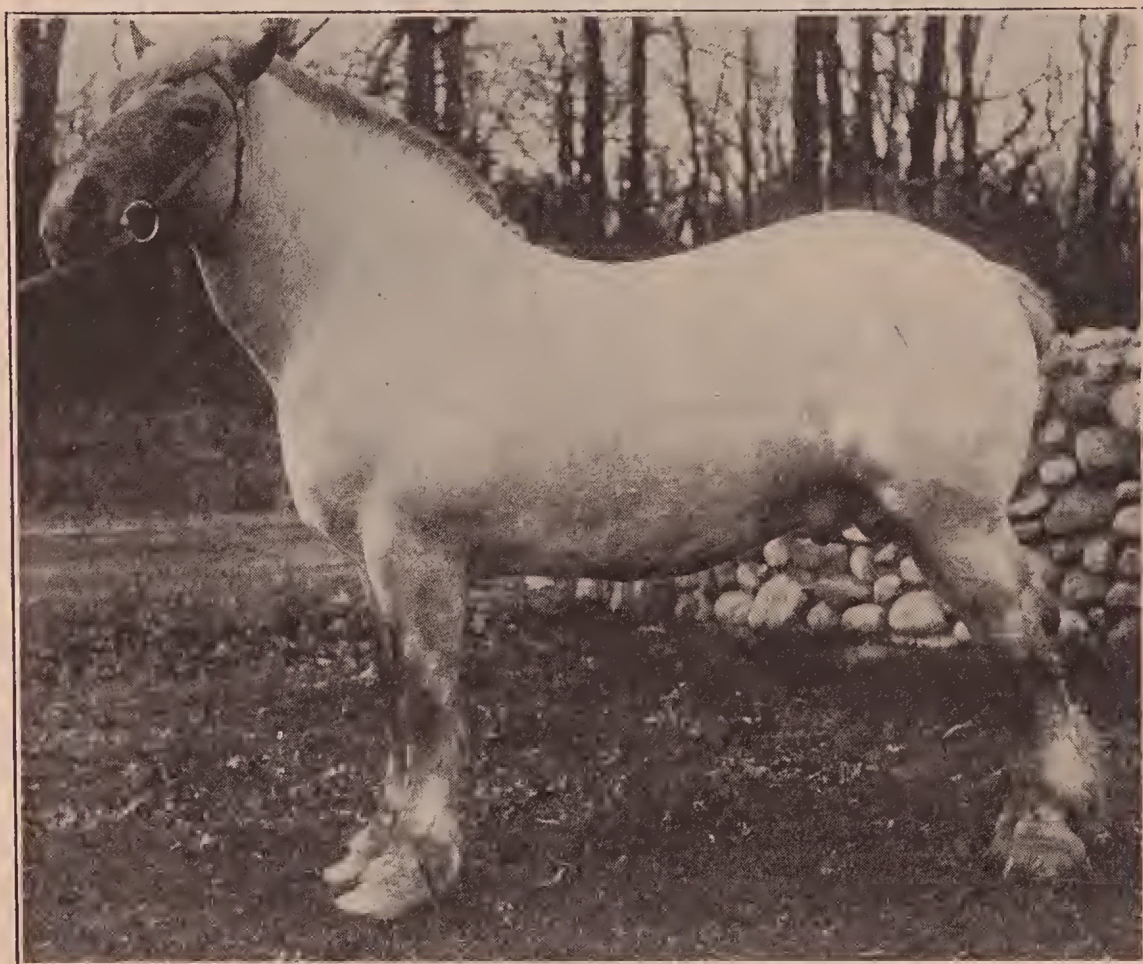

FIGURE 118.—AN INTERNATIONAL CHAMPION DRAFT HORSE OF THE PERCHERON BREED.

Compare the size of the neck, shoulders, and hips with the same parts of the trotter breed in Figure 119. What kind of work can this horse do best?

stages preserved in the rocks, afford examples of the manner in which some of our present animals have developed.

The domesticated horses were developed in the old world. In the warmer regions, where food was plentiful, the largest horses developed, while in the north, where food was less abundant and the conditions were more severe, the Shetland pony appeared. Most breeds of horses were de-

FIGURE 119. — A STANDARD BREED OF TROTTING HORSE.
Compare the various parts of this horse with the draft horse in Figure 118.

veloped in France and England. There are three general types: namely, draft horses, which are the largest and heaviest, with short, strong limbs and thick necks, of which the Percheron, Belgian, and Clydesdale are common types; coach or carriage horses, which are graceful and plump but not so heavy as the draft horses; and roadsters or trotting horses, which are the lightest and slimmest of the horses. Roadsters have long legs, a thin neck, and are noted for their intelligence. Saddle horses belong in this third class (Figure 119 a fine specimen).

FIGURE 120. — DEER MOUSE.
A nocturnal rodent. A flashlight photograph.

The mule has been known for many centuries. Even in the days

of ancient Greece and Rome mules were used in agriculture. They are stronger, more patient, live longer, and are surer footed than horses. Because of their great endurance and adaptability, they are more widely used than horses.

104. The Cow. — Cattle are descended from the wild ox of Europe and Asia, and practically all our popular breeds

FIGURE 121. — HOLSTEIN COW AND CALF.

This cow gave 653 pounds of milk in seven days and 101 pounds in one day. The 653 pounds of milk yielded a little over thirty-three pounds of butter. This is one of the highest records ever made. The Holstein breed of cows is also as good for beef as they are large.

have been developed in Europe, mainly in the British Isles. There are two main types of cattle: the beef type used for food and the dairy type most valuable for the milk, butter, and cheese that they produce. The beef type is characterized by "blocky" bodies, a form which yields the greatest quantity of meat. The beef cow is not expected to produce much milk. Shorthorns and Herefords, English breeds, also Angus and Galloway, Scotch breeds, are good repre-

sentatives (Figure 122). The dairy type presents a different appearance from the beef type, having much less regular bodies and very large udders. The Island breeds, Jersey and Guernsey, are among those most famous for the production of butter fat rather than for the quantity of milk. Jerseys are especially valuable as family cows.

FIGURE 122. — A PRIZE HEREFORD BULL THAT SOLD FOR $15,000. The Herefords are a breed of cattle especially raised for beef. Why?

Guernseys, larger and heavier than Jerseys, yield more milk and more meat. The Ayrshires, a Scotch breed, are known for the superiority of their milk for cheese, for the large proportion of butter fat, and for the fact that they yield more beef than any other dairy breed. Dutch cattle, the Holstein-Friesian breed, are famous for the quantity of milk that they produce. The milk is superior for cheese-making and, on account of the large quantity they produce, these cattle rank foremost in supplying cities with milk.

Oxen of this breed grow to large size and are much prized as work animals (Figure 121).

105. Sheep. — Sheep have been domesticated for ages, being possibly the first mammals domesticated by man. They thrive in nearly all climates and can find food where other mammals can scarcely live. Sheep furnish wool and meat. There are three classes, based on the quality of the

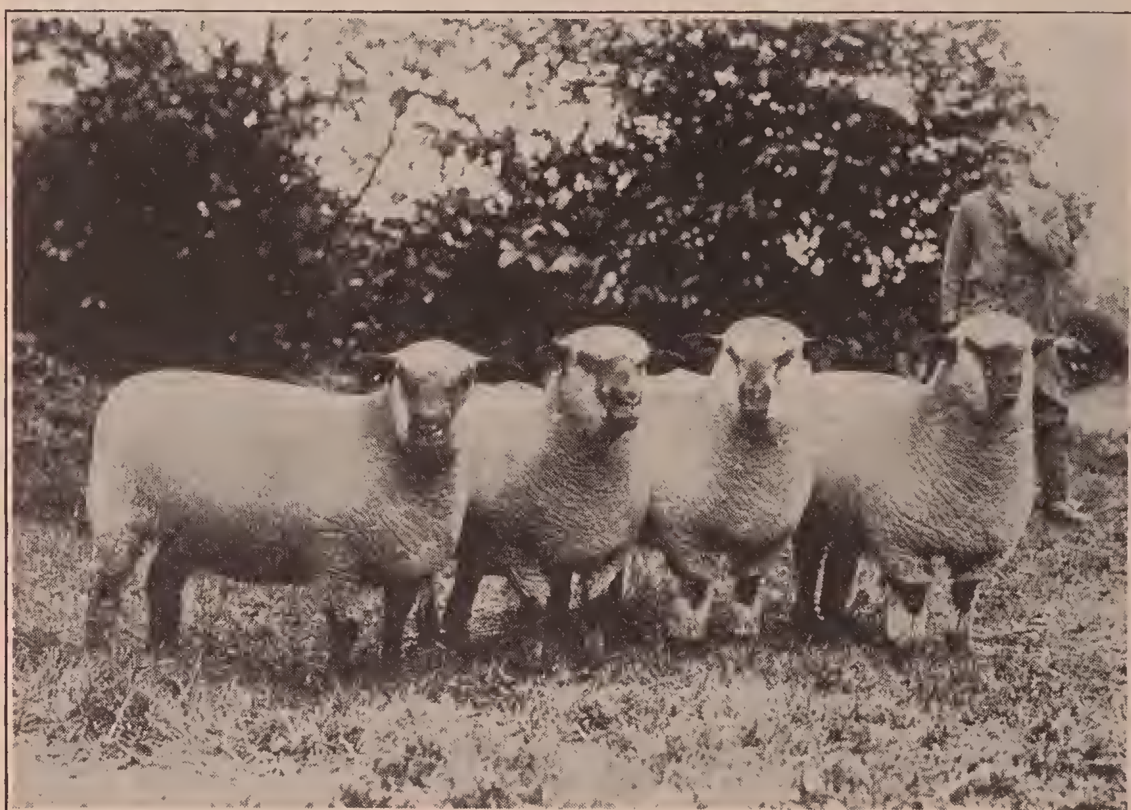

FIGURE 123. — TWO YEARLING EWES AND TWO EWE LAMBS.
The famous Hampshire breed of coarse wool sheep. Compare with Figure 124.

wool. These are the fine wool breeds like the Merino, which had its origin in Spain, whence they have been carried to all countries where sheep raising is an important industry; the medium wool breeds like the Southdown; and the long wool breeds like the Leicester, both of which are English breeds. The fine wool breed is raised principally for the wool, the meat value being a secondary consideration. The medium wool breeds are raised principally for the meat and

wool is a secondary consideration; while in the long wool breeds the mutton and the wool are of equal importance. Closely related to the sheep are the goats, which are the main dependence for milk and meat in the Island of Malta, Switzerland, and Asia Minor.

106. Pigs. — The pig has been developed from the wild boar of the old world. Meat is obtained more cheaply from the pig than from any other animal, because it adds

FIGURE 124. — A GROUP OF RAMBOUILLET SHEEP.

These are the most famous of the fine wool breeds of sheep. They yield a large fleece of wool and are valuable as mutton. Compare with Figure 123.

more weight for a certain amount of food than either sheep or cattle and does it in a shorter time. There are two types in our markets, the lard type and the bacon type, which are produced largely through the methods of feeding. The well-known Berkshires, an English breed, whose color is black, are regarded by many as the aristocrats among pigs. America is famous for the breeds of pigs developed here, of which the Poland-China, originating in Ohio, the Chester White, first produced in Chester County, Pennsylvania, and the Duroc-Jerseys, of New Jersey, are among the most popular.

107. Economic Importance of Mammals. — In his relations with the organisms about him, man finds some helpful, some harmful, and some neither. As we have seen, the domesticated mammals, especially the horse, cow, sheep, goat, and pig, are of the greatest use to man in this part of the world. In cold regions, reindeer are the main dependence for food, clothing, and for beasts of burden. In desert regions, the camel is the most useful and in hot regions elephants are of great value as beasts of burden. Dogs and

FIGURE 125. — BERKSHIRE PIG-MOTHER AND FAMILY.
This is one of the famous American breeds of pigs.

cats have long been man's companions. Of the wild mammals, seals and walruses, which live in the water, furnish food, fur, and leather. The whale furnishes whalebone, food, and oil.

Man is learning to make use of the habits of other mammals; for example, we build roosts in the vicinity of swamps and marshes to furnish shelter for bats by day. At night the bats fly about catching the insects which annoy man and his animals. There are harmful mammals, too, such as gophers (gō′ferz), prairie dogs, and rabbits, which

injure man's land and his crops. Rats and mice consume much food and destroy much that they do not eat, besides carrying diseases. Red squirrels gnaw their way into houses, where they damage beds and furniture, and out of doors they destroy the eggs and young of birds.

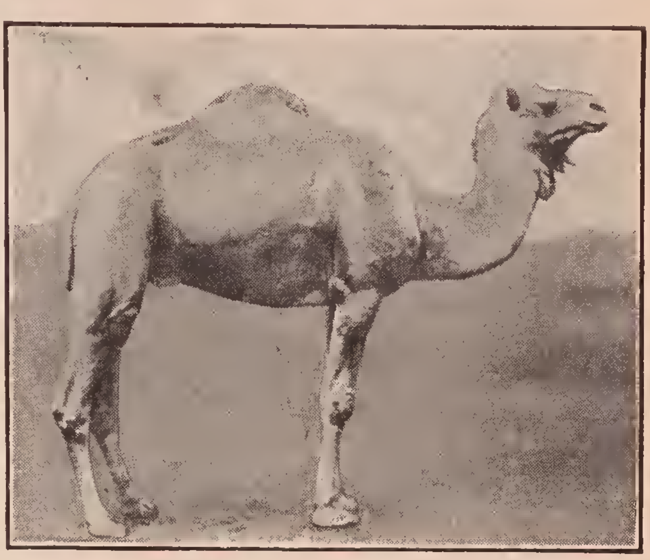

FIGURE 126. — CAMEL. THE SHIP OF THE DESERT.

In making long trips across the desert, the camel is able to go without drinking. During these journeys, the hump grows smaller as the fat in it is used as food. This food is gradually changed until part of it becomes water. We might say that the fat in the camel's hump is a special water reservoir.

Rats,[1] mice, and guinea pigs have proved of great use in laboratories where the causes and effects of diseases are studied. Their reaction to diphtheria, tuberculosis, cancer, and other diseases is similar to that of man. As a result of these studies the skillful physician is more successful in relieving the sufferings of man.

Report on Mammals to be filled out first from general knowledge, later extended by trips to fields, woods, or parks.

KINDS	WHERE FOUND	FOOD	KIND OF FOOD	LIFE IN WINTER	LIFE IN SUMMER	BENEFICIAL	HARMFUL

[1] The Brown Rat causes damage to cereals and grains estimated at more than $200,000,000 annually in the United States. Read "The Brown Rat in the United States," by David Lantz. Bulletin No. 33, Biological Survey, United States Department of Agriculture.

FIGURE 127. — BISON.

These sturdy animals once roamed the plains in great numbers. If they had not been protected in park preserves, they would now be extinct.

FIGURE 128. — A BEAVER DAM.

Describe how it is made.

Lions and tigers sometimes kill human beings. Weasels, skunks, and mink do harm by killing poultry.

108. The Beaver. — The beaver is one of our most interesting mammals because of its social habits and architectural ability. The demand for its fur and oil has led to its extermination in many parts of the country. In the Adirondacks they were trapped and hunted with such vigor that for a few years previous to 1905 none was to be found.

FIGURE 129. — YOUNG POPLAR TREES CUT DOWN BY BEAVERS. Notice the top of the stump.

In 1905 several pairs were obtained from Yellowstone National Park and liberated near the old beaver haunts in the Adirondacks, and at the same time laws were passed protecting them. Now they are numerous throughout the Adirondacks wherever natural conditions are favorable. The beaver is frequently selected as an emblem of industry. Some of the interesting facts in connection with the life of the beaver follow.

1. With their strong teeth they are able to cut down trees more than a foot in diameter.

2. They cut up the trees into lengths which they can handle in the water (Figure 129).

3. If the trees are large and there is no water near, they dig canals leading back to the fallen tree.

4. They build dams that are eight or ten feet high and twenty or thirty feet wide. These dams frequently raise the level of lakes so that the shore line is changed (Figure 128).

FIGURE 130. — A BEAVER HOUSE.
What is it used for?

5. If the stream is large and the pressure on their dam becomes too great, they build a secondary dam below the first one, which provides slack water and thus protects the main dam.

6. Their houses are built of mud and sticks on the margin of the ponds after the dam is finished. They live in these houses and enter them from below the surface of the water. The purpose of the dam is to provide a pond with deep water for their protection and use (Figure 128).

Beavers live in colonies and work industriously in building dams and houses. Some damage is done by their cutting trees and damming up streams. The great popular interest in beavers and their works more than outweighs the little harm they do.

FIGURE 131. — RUNWAYS OF MUSKRAT.

As the water in the pond recedes, the muskrats dig canals that enable them to reach water from their lodges in the bank without going over land. How does this show adaptation in the behavior of these animals? These canals are often mistaken for beaver runways.

SUMMARY

The animals which are called mammals are covered with hair and nourish their young with milk. There are nearly always two pairs of appendages that undergo much modification, according to the habits of the animals. Our domestic animals which serve us in so many ways have gradually developed into their present form and usefulness. Man had to learn first how to use the fur and skin of wild animals, then how to improve the quality of the fur and skin by careful feeding and breeding of the domesticated animals.

FIELD SUGGESTIONS

If you are where you can visit a zoölogical park it is an easy matter to learn how to distinguish the different mammals, a thing which every one should be able to do. There is another line of study which consists in selecting some one or two of the common mammals, such as squirrels, and making a thorough study of them from week to week, month to month, year after year, until you feel thoroughly acquainted with them. A third line of study is that of hibernation. Some mammals do not hibernate, some do so only during cold snaps, while others go to sleep for the entire winter. Consult, Walter B. Taylor, *Suggestions for Field Studies of Mammalian Life-histories* — United States Department of Agriculture, Department circular 59, 1919.

QUESTIONS

How do you tell a mammal from other vertebrates? What mammals live near your home? What do they eat? Where do they spend the winter?

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Stone and Crane, American Animals.

CHAPTER IX

THE SIMPLEST ANIMALS — PROTOZOA

109. Definitions. — In our study of the grasshopper and its insect relatives we considered their behavior and life processes. If we had studied the minute structure of any of these insects, the grasshopper, for example, and had used a microscope to aid us, we should have found that every organ was made up of numerous small parts joined together in a definite manner. These small parts are called *cells.*

Any book on biology uses the word *cell* again and again. The name was first used by the Englishman, Robert Hooke, over two hundred years ago, when, with his crude microscope, he examined a piece of bark and found it to be made up of little rooms which looked like the cells of the honeycomb. These spaces he named *cells.* When better microscopes were made, the living parts of the cell were discovered, and it was found that Hooke had seen only the walls of dead cells.

All plants and animals are composed of cells. A cell may exist alone, carrying on all the life processes itself, or it may exist in connection with a great many other cells, as in all large animals and plants. In every case each cell is produced from another cell.

There are certain animals that are never more than one-celled even when they are full grown. These animals are called *Protozoa* (prō-tō-zō′a: Greek, *protos,* first; *zoön,* animal).

110. The Protozoan Cell. — *The protozoan cell is a single mass of living matter, called* ***protoplasm.*** In a general way it carries on the same life processes as the grasshopper, or

any other animal. When this living cell comes in contact with heat, cold, electricity, chemicals, or other stimuli, it moves, and we say that it is *irritable.* The term *irritability,* used with a scientific meaning, is defined as the *power of being aware of a stimulus.* When this living cell is brought into contact with cold, for example, it makes a definite movement. It is aware of the cold stimulus.

The living cell grows by using food. It takes in oxygen from the water or from the air, according to where it happens to live. It gives off waste substances. It can grow and reproduce other cells of the same kind.

FIGURE 132. — PHOTOMICROGRAPH OF AN AMŒBA.

Many protozoan cells have no limiting wall between the living substance and the water in which they live. Yet the protoplasm and the water do not mix, though we do not understand why. Other Protozoa living in the ocean are surrounded by extremely thin skeletons of lime. When the animals die their skeletons sink to the bottom and become massed in a sort of rock. The famous chalk cliffs of England were formed in this way.

111. Habitat. — The *habitat* of any animal is the place where it lives. The Protozoa are small, usually microscopic, animals common in stagnant pools and in swamp water. They are also common in salt water. In fact, Protozoa are likely to be found in nearly all ponds of water that contain food for them. Often, in the summer time, our attention is called to the activities of Protozoa when the water from lakes or reservoirs has a fishy taste. This

peculiar taste may be due either to animals or plants, or to both. When it is due to animals, it is caused by a disagreeable oil formed by a certain kind of Protozoa.

By far the greater number of Protozoa are harmless, and many are helpful to us in that they serve as food for fishes. Others, however, may become parasitic in our bodies, and thus cause such diseases as malaria, yellow fever, or sleeping sickness.

112. Amœba.[1] — The name *Amœba* (a-mē'ba) is given to several different Protozoa, but all represent the simplest form of animal life known to us. For this reason they are always studied in biology. In order to describe correctly the structure of even so simple an animal as the amœba a few new words are necessary.

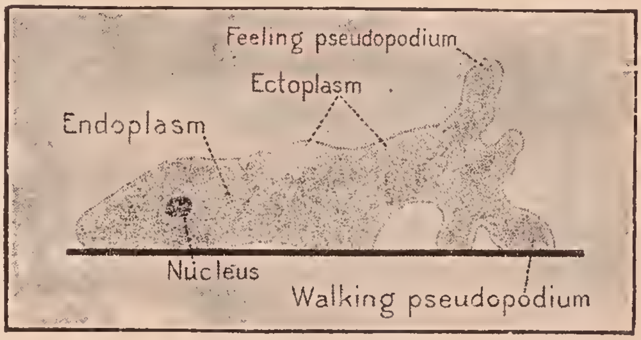

FIGURE 133. — DIAGRAM OF AN AMŒBA.

Structure of Amœba. — It is difficult for inexperienced students to see the living amœba through the microscope, because the whole cell has a faint, grayish appearance, and in a strong light is transparent. But if this grayish appearance of protoplasm is once seen, it is always remembered.

There is no well-defined cell wall; therefore the amœba

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[1] No suggestion can be made which will always enable the teacher to secure amœbæ. They are more frequently found in the slime and mud of stagnant water than anywhere else. Paramecia and other infusoria can usually be secured in abundance by placing a handful of hay or leaves in a jar and covering them with the ordinary water used in the laboratory. This is called a *protozoan culture,* and should be started about four weeks before the material is wanted for class study. The length of time that the culture should stand can be lessened by adding a little beef-extract and by keeping the jar near a radiator. Water sufficient to keep the hay or leaves covered must be added from time to time. When a good culture of Paramecia is once secured, the jar should be kept from year to year, simply adding water to the dried hay left in the jar when Protozoa are desired.

is an illustration of a living, naked cell. Near the center of the cell is a spherical mass of denser protoplasm called the *nucleus*. In many amœbæ the nucleus is not easily seen except by means of specially stained preparations. The rest of the protoplasm in the cell is called *cytoplasm* (sī′tō-plazm). This does not appear the same in all parts of the amœba. On the outside, there is a thin, almost transparent layer, called *ectoplasm* (ek′tō-plazm: Greek, *ecto*, outside; *plasma*, form). The larger part of the cytoplasm is filled with numerous small granules and contains several vacuoles. This inner mass of cytoplasm is called *endoplasm* (en′dō-plazm: Greek, *endo*, within; *plasma*, form). The vacuoles in the endoplasm may contain food, water, or waste products. The food and water vacuoles are temporary structures, but the vacuole which collects the liquid waste is always present.

The living amœba is continually changing shape and pushing out from the surface of its body blunt, finger-like projections of the protoplasm called *pseudopodia* (sū-dō-pō′dĭ-a: Greek, *pseudo*, false; *pod*, root of *pous*, foot), which give an irregular outline to the body (Figure 132). Sometimes the pseudopodia branch out, and therefore the scientific name *Rhizopoda* (rī-zop′ō-dä: Greek, *rhizos*, root; *pod*, root of *pous*, foot) is the technical name for all amœba-like Protozoa.

113. ***Motion.*** — The amœba sends out a pseudopodium, and gradually the rest of the body flows, by a rolling movement, in the same direction. This creeping-rolling motion of the protoplasm enables the amœba to move through the water.

114. ***Nutrition.*** — When the pseudopodium comes in contact with a minute plant upon which the amœba feeds, the protoplasm of the pseudopodium surrounds the plant and takes it into the cell. The microscopic plant thus eaten by the amœba is inclosed, with a small amount of water, in a tiny globe called the *food vacuole* (vāk′ū-ōl). The food vacuole is to be thought of as a stomach in which digestion

can take place, for the plant is digested in it. Digestion is accomplished by means of an enzyme. The nutritious parts are absorbed into the protoplasm, the undigested parts are cast from the cell, and the food vacuole disappears.

Food vacuoles are not always round (Figure 135), but take their shape from the form of the plant eaten. If a filament of alga, page 304, is taken as food, the food vacuole is much elongated.

115. ***Respiration.*** — From the air dissolved in the water, the amœba obtains by osmosis the oxygen necessary to its life, and it gives off carbon dioxide from the cell.

116. ***Excretion.*** — The term, contractile vacuole, is given to the vacuole which is always present in the protoplasm of amœba. This vacuole can be seen to increase slowly in size, then suddenly contract. As it contracts, the fluid in it is forced to the outside of the body of the amœba. The filling out of this vacuole is due to the collection of excretory wastes from the surrounding protoplasm. It is called a contractile vacuole because it contracts and expands, and an excretory vacuole because it collects waste products.

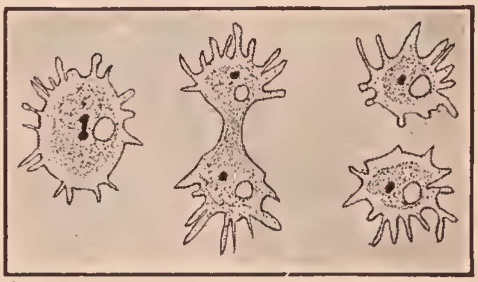

FIGURE 134. — THREE STAGES IN FISSION OF AMŒBA.

117. ***Reproduction and Encystment.*** — The chief method of reproduction in the amœba is simple (Figure 134). The living cell divides into two equal parts, forming two new cells. This process is known as *fission* (fĭsh′ŭn: Latin, *fissus*, cleft).

When the food or water becomes unsuited to supply the needs of the cell, in order to live the amœba often secretes (makes for itself) a thick wall completely surrounding the protoplasm. This process is termed *encystment* (en-sĭst′-ment: Greek, *en*, in; *kystis*, bladder). After the wall has been formed, the amœba is able, for a long period, to resist cold, the drying up of the pond, or the lack of food.

118. Paramecium. — One of the most common forms of Protozoa is the slipper-shaped *Paramecium* (para-mē′-shĭ-um), which is more active than the amœba. It is abundant in stagnant water and in the hay infusions prepared in the laboratory. (See Laboratory Suggestions.)

LABORATORY STUDY

There are certain kinds of Protozoa that are usually found in protozoan cultures. The most abundant form is the paramecium. Make repeated examinations of drops of water from the protozoan culture, until you are able to find the paramecium. Notice its shape, rate of movement, behavior on meeting obstacles, and the like. Report on what you can make out. Compare the paramecium with any other protozoön you can find, as to shape, rate of movement, size, color, etc. If available, examine slides which show the nucleus of a protozoön. Make sketches that illustrate the above features.

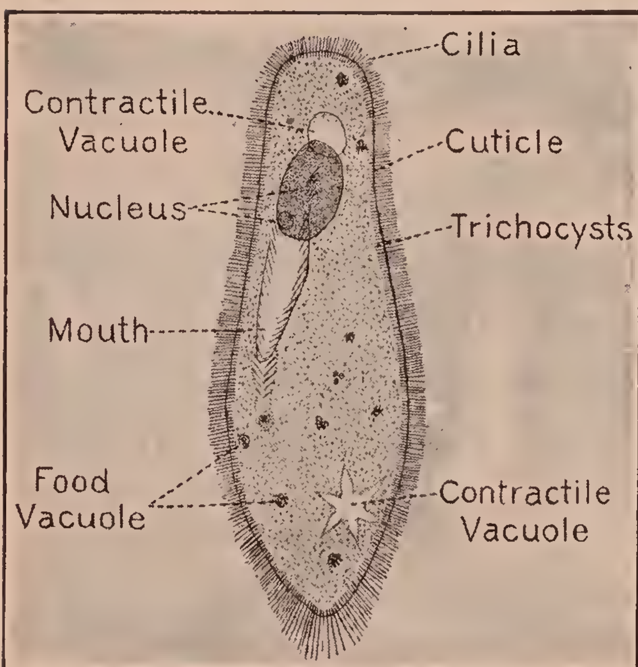

FIGURE 135. — DIAGRAM OF PARAMECIUM.

Structure of Paramecium. — The paramecium, like the amœba, is a single cell, but it has both a large nucleus and a small one. It has an endoplasm, an ectoplasm, and a *cuticle* (kū′ti-kl), or cell wall. Through the cuticle there extend great numbers of *cilia* (sĭl′i-a), or threads of living protoplasm. The ectoplasm contains many thread-like darts known as *trichocysts* (trĭk′o-sists). These can be discharged. Within the cell are found food and water vacuoles as in the amœba; but there are two contractile vacuoles, one at either end, and the food and water vacuoles are more numerous than in amœba.

119. Locomotion and Defense. — The animal moves by

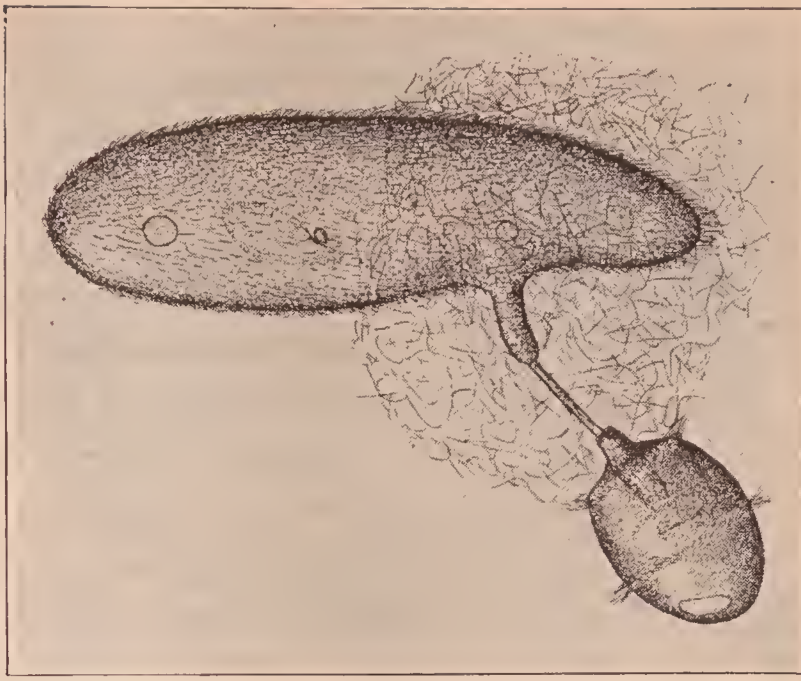

FIGURE 136. — PARAMECIUM.

Being attacked by another protozoön that feeds upon it. The trichocysts are discharged, and they force the foe away.

the action of the cilia, the direction being due to the angle at which the cilia are held. It can be observed that the animals move backward and forward, and that they also rotate on the long axis. Paramecia defend themselves by discharging their trichocysts. This discharge occurs either as a result of certain strong artificial stimuli, such as electric currents or chemicals, or naturally because of collision with certain other Protozoa. If attacked by some animal which feeds upon them, they discharge the trichocysts in the region of the attack (Figure 136).

FIGURE 137. — PARAMECIUM STAINED TO SHOW THE NUCLEUS (Photomicrograph).

120. Nutrition. — The paramecium, like all other living things, requires food, which consists mostly of bacteria. These are collected by means of the cilia located on each side of the fold or depression called the gullet. At the inner end

of the gullet is the mouth (Figure 135). The food thus collected passes into the protoplasm in the form of food vacuoles. Digestion is accomplished by the aid of enzymes which put into solution the available parts of the food it eats, and the indigestible parts are cast off from the body.

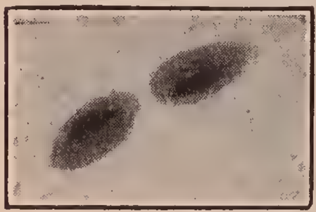

FIGURE 138. — PARAMECIUM REPRODUCING BY FISSION.

Compare the shape of the nucleus with the one in Figure 137.

121. Respiration. — As in amœbæ, the oxygen which is necessary to respiration is obtained directly from the water and passes into the protoplasm at all points.

122. Excretion. — Excretory wastes are first collected in each of the two contractile vacuoles and then cast from the body. Gases escape from the entire surface.

123. Irritability. — Both the amœba and paramecium respond to jars, food, and their enemies in a definite manner. In each of these simple cells there is no structure which can be compared to the nerve cells or brain of higher animals. The ability to respond to stimuli in Protozoa seems to be a condition that is present in the whole protoplasm of the cell.

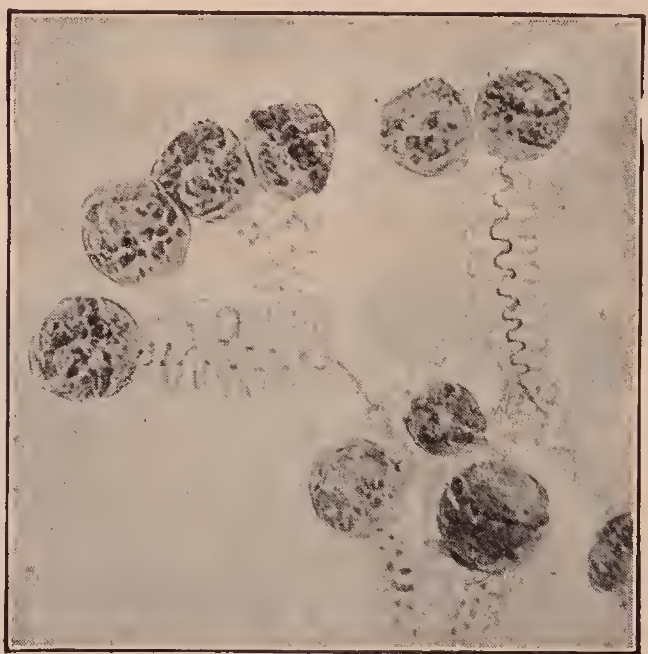

FIGURE 139. — VORTICELLA.

This protozoön is supported on a stalk which can contract and expand. Of what use would this be ?

124. Reproduction. — Paramecia reproduce by fission, *i.e.* an animal divides, producing two; these divide and produce two more. The process of fission goes on indefinitely (Figure 138). Unlike the amœba these forms cannot encyst when conditions of life become unfavorable.

125. Economic Importance. — Paramecia consume considerable quantities of bacteria, but whether more harmful than helpful ones cannot be told. Therefore their economic value is uncertain.

126. Other Protozoa. — If one examines stagnant water, a large number of other kinds of Protozoa will be found. The more common forms are much like the paramecium and have many cilia on the body. Several of these large, ciliated Protozoa feed on the smaller Protozoa. Some of the common forms are shown in Figures 139–141.

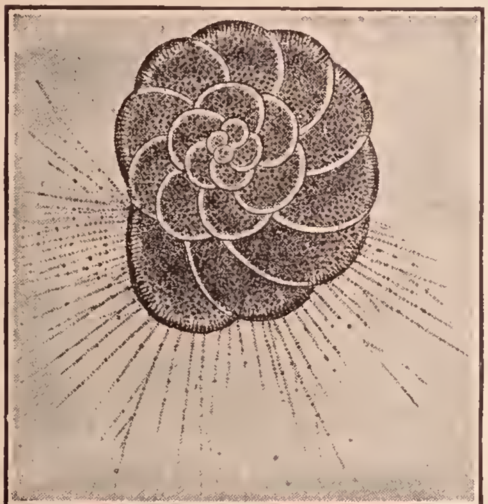

FIGURE 140. — ONE OF THE FORAMINIFERA.

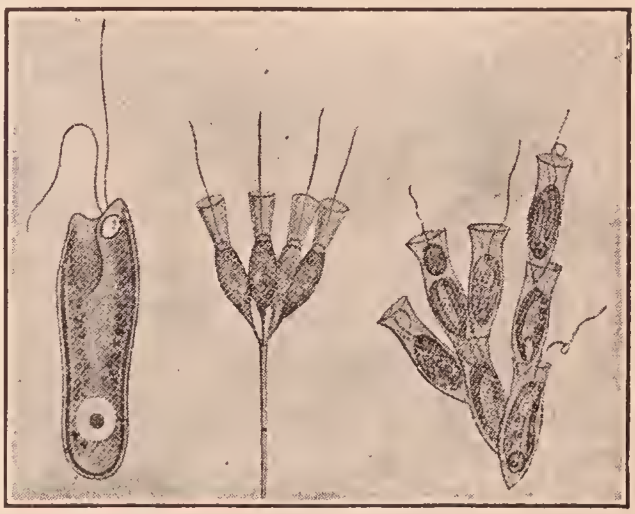

FIGURE 141. — SOME FLAGELLATE PROTOZOA.

All these various Protozoa can be grouped into classes, each with certain distinct characteristics. For instance, all Protozoa that have pseudopodia are called *Rhizopoda*. In this group, the cells may be naked or may possess a hard mineral covering; a second group of Protozoa are provided with one or more long, wavering threads called *flagella* (flā-jel′la: Latin, *flagellum*, whip), and have the name *Flagellata;* the flagella are longer than cilia and exhibit more complicated movement. A third class, known as *Infusoria* (in-fū-sō′ri-a), includes most of the common Protozoa found in protozoan cultures. Most of this class are provided with cilia.

LABORATORY STUDY OF PROTOZOA

Take a drop of water from an infusion rich in Protozoa; place on a slide and examine with a 16 mm. or $\frac{2}{3}$ objective. Answer the questions suggested by the report.

Number of Kinds Observed	How Many Kinds —				How Many Kinds Have —	
	are free swimming?	are attached by threads?	have even motion?	have zigzag motion?	constant form?	varying forms?

127. Protozoa and Alcohol. — Scientists have studied the relation of alcohol to the life processes of Protozoa. Normally, such Protozoa as Paramecia divide a regular number of times each day. When a small amount of alcohol is placed in water containing Paramecia, the normal rate of fission is diminished. Professor Woodruff has shown by an extended and critical study that alcohol tends to prevent Paramecia from dividing as many times as they would under normal conditions. This means that alcohol hinders the growth of Paramecia.

SUMMARY

Protozoa are the simplest group of animals. They are found mostly in water, yet some are parasitic in higher animals. They are small and usually consist of only one cell. They reproduce mostly by fission. Some produce diseases in man and beast, such as malaria and the sleeping sickness of Africa. But the great majority of Protozoa are not harmful.

QUESTIONS

Compare the body of a protozoön with the body of a grasshopper. In what are they alike? In what different?

How do the amœba and paramecium compare?

Explain how the Protozoa eat, digest food, produce more Protozoa, and protect themselves.

How do these vital processes compare with the similar vital processes in the grasshopper?

In what ways are Protozoa injurious to man? Are they parasitic?

REFERENCES

Galloway, First Course in Zoölogy, Chapter X.
Hegner, Introduction to Zoölogy, Chapters IV, V, VI.
Jordan and Kellogg, Animal Life, Chapters II, III.
Kellogg, Animals and Man, Chapter V.
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CHAPTER X

THE SIMPLER METAZOA

128. Metazoa. — The Protozoa just studied are single, free, living cells, while the grasshopper is made up of thousands of cells. The grasshopper is called a *metazoön* (mĕt-a-zō′on: Greek, *meta*, later; *zoön*, animal) because there are many cells in its body. The Protozoa and the Metazoa are alike in that both take in food, breathe, give off waste matter, and reproduce their kind.

FIGURE 142. — GONIUM.

There are a number of organisms concerning which scientists disagree as to whether they are plants or animals. In zoölogy, these forms are known as Colonial Protozoa or simple Metazoa. We shall study two of these (gonium and volvox) and then examine the sponges, which all scientists agree are Metazoa.

129. Gonium. — Gonium is an animal made up of sixteen separate cells held together by a mucilage-like secretion of the cells. Each cell works independently in getting food, breathing, giving off waste, and in reproduction. The colony moves by lashing the water with long protoplasmic threads (flagella), two of which project from each cell. The advantage in rate of movement resulting from the union of cells is

illustrated in rowing. Eight men in a large rowing shell can go faster than one man in a single, small shell. In reproduction, the sixteen cells fall apart, and each one grows into a new colony.

130. Volvox. — *Volvox* is a colony of hundreds of tiny green cells embedded in a hollow gelatinous sphere. Each cell has two flagella. For a time all the cells are alike and share equally in the work of the colony. But in reproduction only a few cells take part. In the simplest method, a few cells grow large and escape into the hollow sphere. There, they divide and grow into new colonies. Finally, the mother colony breaks, and the daughter colonies escape.

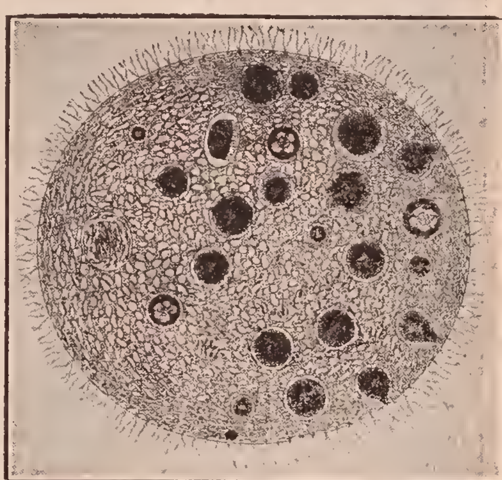

FIGURE 143. — VOLVOX

The more complex method is like the reproduction of higher animals. Certain cells in the colony grow large and escape into the hollow sphere. They are the *egg cells*. Other cells of the colony enlarge and divide into large numbers of slender, free-swimming cells called *sperm cells*. The sperm cells escape into the hollow sphere and swim about. One sperm enters an egg cell and unites with it, forming a single cell, the *fertilized egg cell*, which can develop a new colony.

131. Division of Labor. — In gonium, the cells are alike in form and function, but in volvox, we find that a few cells have been changed in form in order to perform better the special work of reproduction. This is the first step in the division of labor.

This is well shown in the higher animals, where certain cells are grouped together for a given work. The digestive system contains cells which work to make solutions of the food eaten. These solutions nourish the whole body,

not the cells of the digestive tract alone. Certain other cells are modified in such a way for secreting and holding lime that they form bones by which the whole body is benefited.

Some cells are grouped to form muscles to be used in securing food and in enabling animals to escape from their enemies. Other cells are for the purpose of conveying and

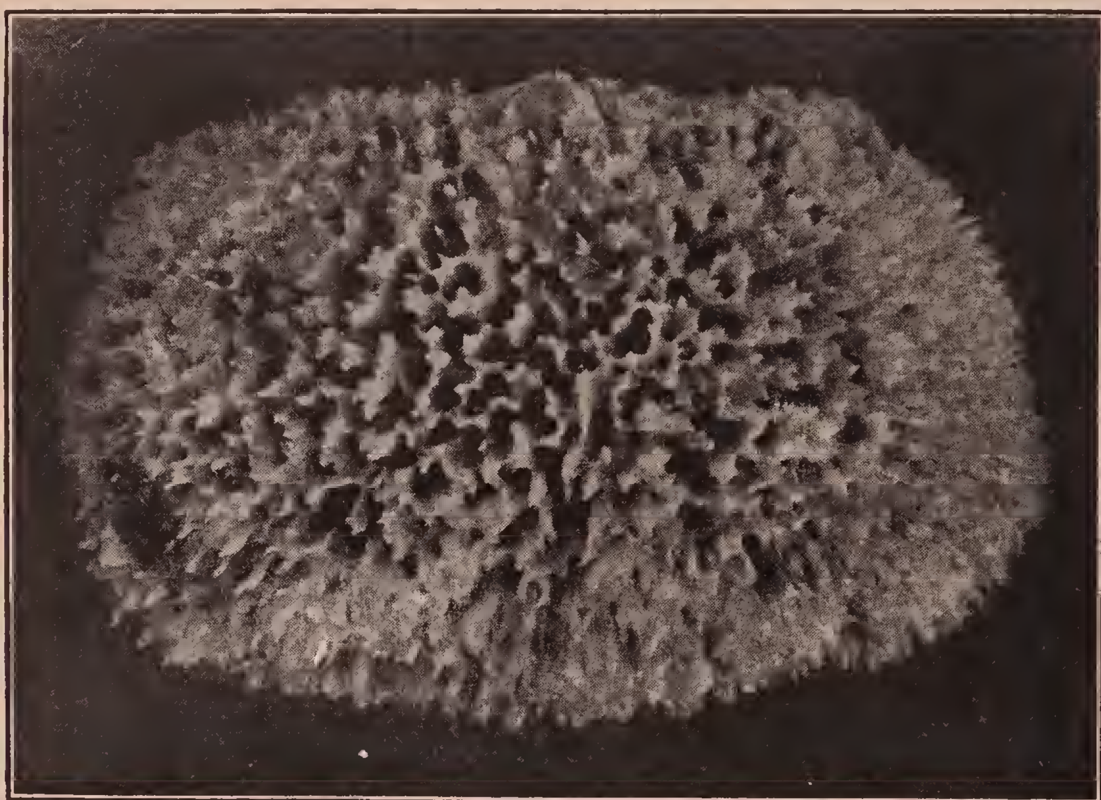

FIGURE 144. — BATH SPONGE. A SKELETON.

interpreting impressions, so that the animal may hear the approach of an enemy, or detect the presence of food. It is largely the carrying out of this " division of labor " that tells us the rank of an animal or a plant in biological classification.

In the business world we have a somewhat similar division of labor. Years ago the cobbler made all the parts of a shoe. In our large shoe factories to-day we find no one man making an entire shoe. One man runs the machine that cuts the leather and he does no other part of the work. He may have been a cutter twenty years, and he works rapidly and ac-

curately. Another man runs the machine which sews uppers to the soles. He, too, is a rapid and skillful worker. Other men have their special lines of work to do. In the end they produce more shoes and better shoes than this same number of men could, if they were all cobblers and each finished his product.

132. Sponges. — Sponges are simple Metazoa. In them we find division of labor carried out in a more complex way

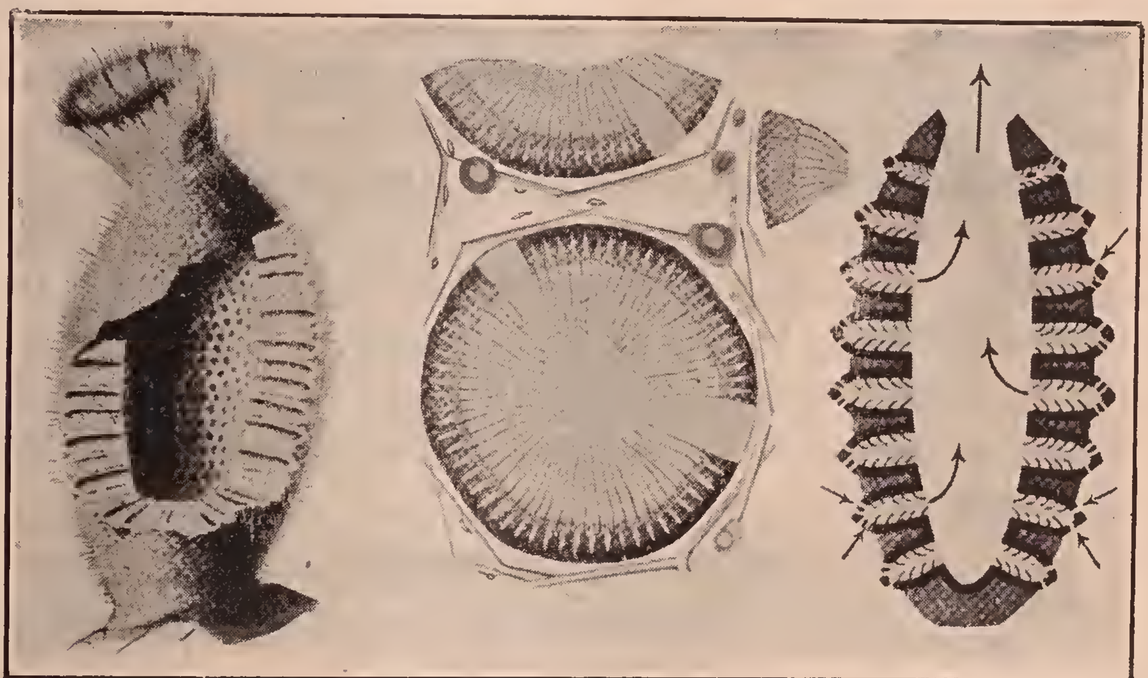

FIGURE 145. — THE SPONGE KNOWN AS GRANTIA WITH PART OF THE WALL REMOVED.

Water enters through minute pores in the side of the sponge and escapes through the large opening at the top.

than in gonium and volvox. Simple sponges have a body in the form of a hollow cylinder. Water enters through the sides of the body and passes out through a hole in the top. A simple sponge, called *Grantia*, grows in salt water attached to docks or other objects submerged along the seashore. On examination, it will be observed that grantia is less simple than volvox.

133. Structure. — Grantia is composed of three layers of cells which show division of labor. The inner layer is called the *endoderm* (en′dō-derm). It consists of cells provided

with flagella which, by their movement, produce a current of water through the central cavity. The water enters through the holes in the sides (inhalent pores) and is forced out through the opening at the top pore (exhalent pores). The water contains food particles which the cells of the endoderm have the power to take in and digest. The food solution is passed to the other cells in the sponge body by the process of *osmosis*. This is a process in which gases or liquids of unequal densities, separated by a plant or animal membrane, tend to mix and become alike, the liquids or gases passing through the membrane.

Thus the food digested is passed on and nourishes the cells of the middle and outer layers. The cells of the middle region form *spicules* (spĭc′ūls) of lime (Figure 147) that project through the other layers and strengthen the whole body. The outer layer or *ectoderm* (ek′tō-derm) serves as a protective layer and with the help of the spicules gives definite shape to the body.

LABORATORY STUDY

The sponge which we ordinarily handle is simply the skeleton, and is easily kept from year to year. Examine several kinds of sponge skeletons and compare their shape, size, and the nature of the skeleton. How much water will the pores of the sponge hold? Microscopic sections of Grantia are necessary if you are to make out the inhalent pores, the central cavity, and spicules.

134. Reproduction. — At certain times of the year the sponge reproduces by means of two kinds of cells (eggs and sperms) developed in the middle layer. A sponge may develop both eggs and sperms, but usually develops only one kind at a time. Cells from the middle layer move in between cells of the endoderm and grow large and round. These are the eggs (female cells). Other cells move into the endoderm layer and divide into many small ciliated cells (the sperm or male cells). The sperms are set free and escape into the water of the central cavity and out from the

body of the parent sponge. A sperm enters the body of another sponge and when it finds an egg, fuses with it, thus forming the fertilized egg. The fertilized egg then begins to grow, and after a definite period breaks away from the parent, moves about for a time, and then settles down, attaches itself, and grows into a mature sponge. The immature sponge has the power of locomotion, but the mature form has lost this power. Nevertheless the sponge is an animal.

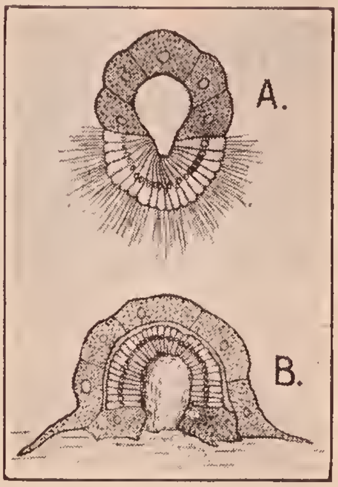

FIGURE 146.

The sponge begins in a single cell that divides into two, then into four. After a while the cells become arranged as in A and the young sponge swims about; as it grows it becomes attached and changes shape as in B.

Reproduction that comes about through the fusion of an egg and a sperm is called *sexual reproduction.* The other method of reproduction, called *asexual reproduction,* also occurs among sponges. By this method, sponges form little buds or branches which develop into new sponges.

135. Spongilla.—*Spongilla* (spŭnj-ĭl′la) is a fresh-water sponge. At the approach of cold weather, certain reproductive bodies are formed, known as winter-cells, and these escape from the sponge. They settle down to the bottom of the pond or stream and remain dormant until the approach of warm weather, when they grow into new sponges. They have a thick protecting coat which enables them to resist unfavorable conditions.

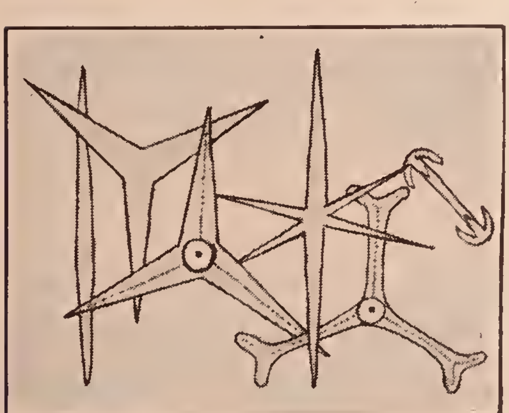

FIGURE 147.— SPONGE SPICULES. Not all these different kinds are found in each sponge.

136. Economic Importance.— The spicules of the different sponges form a large part of their so-called skeletons. These spicules are, in some cases, composed of lime and form the limy

sponges. In others, they are of silica and form the glassy sponges. Sometimes fresh-water sponges grow in the water mains of cities and towns, causing the pipes to become clogged.

The more important sponges have a skeleton made up of a hornlike substance which is flexible. This is the sponge of commerce, great quantities of which are gathered from the sea by divers and by dredges. The living tissues are allowed to decay, and the skeletons are then washed and dried. Some are bleached to form the white sponges. The sponges of best quality come from the Mediterranean Sea and the Red Sea.

The value of the sponge fishery in the whole world annually amounts to about $3,500,000.

137. Relation to Other Animals. — No animal is known to eat the sponge. Sponges themselves feed on minute particles of food, which are carried in by the currents of water produced by the cilia of the endoderm. Some marine animals use the porous body of the sponge as a retreat.

Certain sponges live in close relationship to higher forms of animals. One kind is always found growing on the legs of crabs. The movement of the crab carries the sponge to water richer in oxygen and food, and the crab is hidden from its enemies by its sponge covering. Each animal gains by this inter-relationship. Where two such animals as the crab and sponge live in this way the relationship is known as *symbiosis* (sy̆m-bī-ō′sĭs: Greek, *syn*, with; *bios*, life).

SUMMARY

The transition from simple Protozoa, through the Colonial Protozoa, to the Metazoa is simple and direct. In gonium and volvox, the beginning of division of labor is noticed; that is, one part of the body becomes dependent on another part for certain definite things. For example, one cell is devoted to securing food, while another produces

eggs or sperms. The sponges are simple Metazoa in which the division of labor has taken the form of producing three layers, — the ectoderm, or outer layer; the endoderm, or inner layer; and a loosely formed middle layer. Grantia is a simple sac-shaped sponge which reproduces both sexually and asexually. The general manner of development by the sexual process is essentially the same in all the higher animals, including man. The bath sponges are the only ones of economic importance.

QUESTIONS

What can the single-celled protozoön do? Compare with the Colonial Protozoa, gonium and volvox. Explain the meaning of division of labor in an animal. In what respects do sponges differ? Of what use are they? Why are not all sponges useful?

REFERENCES

Hegner, Introduction to Zoölogy, Chapter VI.
Jordan and Kellogg, Animal Life, Chapter II.
Osborne, Economic Zoölogy, Chapter III.

CHAPTER XI

CŒLENTERATES. HYDRA-LIKE ANIMALS

138. Cœlenterates. — The *Cœlenterates* (sē-len′te-rāts: Greek, *koilos*, hollow; *enteron*, intestine) are simple Metazoa, a little higher in development than the sponges. In this group are hydras (hī′dras), hydroids (hī′droids), jelly-fishes, sea-anemones (a-nem′o-nēz), sea-fans, and corals.

139. Structure of Hydra. — The *hydra* is an interesting fresh-water animal about a quarter of an inch in length. Its body is shaped like a little cylindrical bag with only one opening, the mouth, which is surrounded by a few, usually six, delicate, thread-like arms called *tentacles* (tĕn′ta-kls). The body is composed of three layers, the outer layer, *ectoderm;* the middle layer, the *mesoglea* (mĕs-ō-glē′a: Greek, *mesos*, middle; *gloios*, glutinous substance); and the inner layer, *endoderm*.

Each layer does some particular work for which the others are not fitted. For example, the outer layer contains cells which are especially sensitive to stimuli and many modified muscle cells that enable the animal to move about. The inner layer contains cells provided with flagella which catch the food particles for the inner cells to digest. The muscular action of the outer layer moves the entire animal. The sensitive cells enable the animal to recognize its prey. The food digested by the inner layer is used by all the cells of the body. Thus we see an advance in the division of labor over that shown in the sponge. We shall observe a still greater increase in division of labor as we study higher animals.

Tentacles are hollow, finger-like branches connected with the body cavity. They are provided with stinging cells

which help the hydra to capture living water fleas, and the like. These stinging cells have darts which are automatically discharged when the tentacles come in contact with little animals. The darts stun the prey and render escape impossible. The tentacles surround the food and carry it to the mouth, which opens directly into the food cavity. The action of the tentacles in doing this work suggests the idea that each tentacle has some way of realizing the efforts of the others.

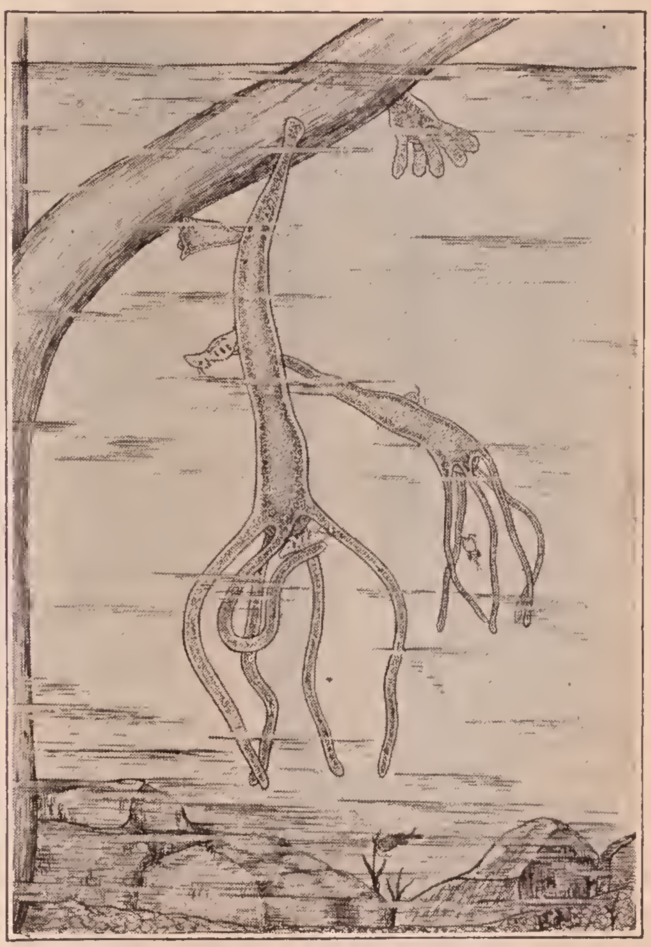

FIGURE 148. — FRESH-WATER HYDRAS.

They are usually found attached to a water plant as in this drawing. The expanded hydra has a nearly full-grown hydra attached to one side and a small bud near the base. Both these young hydras were produced by the method of reproduction known as budding. The larger but very short hydra near the surface of the water is in a contracted condition and would be as long as the larger of the two expanded ones, if it were feeding. The small crustaceans shown in this drawing constitute the main food of hydra. How do they capture them?

We should keep in mind that in the Metazoa the united cells are in connection with one another through the cell walls. This is true even if we are not able to trace the connections with the microscope. In the higher animals we shall find that connections between cells are made by means of nerve cells. The development of a nervous system only carries out division of labor to a greater degree.

140. Locomotion. — The adult hydra is usually found attached as in Figure 148. In this condition the only move-

ments possible are such as take place in the expansion and contraction of the whole body. The tentacles wave about in the water and as the hydra expands, the body may move first in one direction, then in another. In this sense the hydra does not move about as does a grasshopper or a paramecium. At infrequent intervals, however, the hydra detaches itself and moves from place to place by attaching the tentacles, then the base, then the tentacles much like a boy turning handsprings.

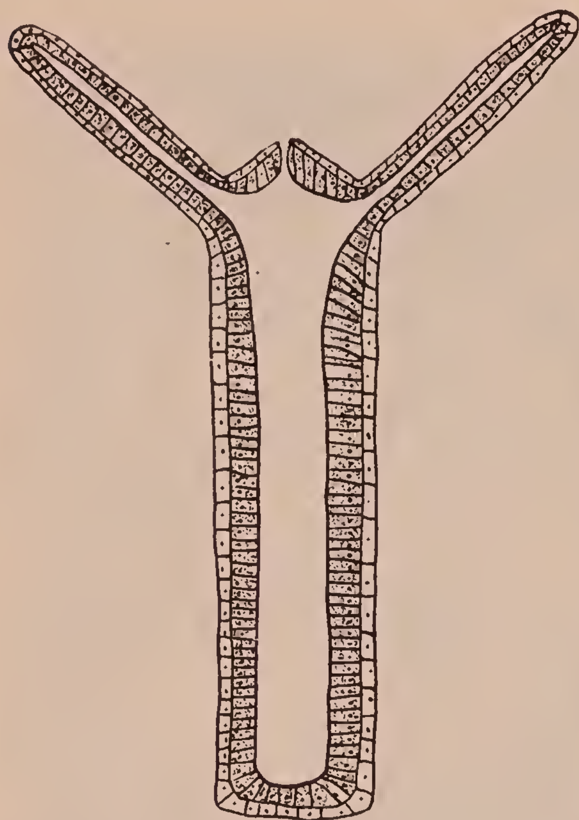

FIGURE 149. — DIAGRAM OF BODY OF HYDRA.

141. Nutrition. — The hydra feeds almost entirely upon minute animals. The forms that furnish the greater amount of their food are shown in Figure 54. These animals belong to a much higher group of animals than the hydra; namely, the Crustacea, the group to which the crayfish and crabs belong. These animals which have an exoskeleton like insects are rendered inactive by the stinging cells on the tentacles. The paralyzed animal is then brought to the mouth by the tentacles, Figure 148, and swallowed. Within the body, the nutritive parts are digested by enzymes as in other animals and absorbed, passing by osmosis to all the cells. The undigesti-

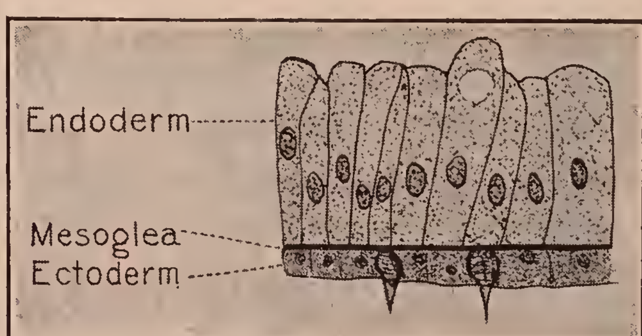

FIGURE 150. — CROSS SECTION BODY-WALL OF HYDRA.

ble skeleton of the animals eaten is cast out through the mouth.

142. Respiration and Excretion. — By osmosis, oxygen is absorbed from the water by the cells of the ectoderm. The water that enters the mouth carries oxygen, and by osmosis it is absorbed by the cells of the endoderm. At the same time the carbon dioxide from the cells is thrown off into the water.

143. Irritability. — The hydra is able to appreciate a variety of different kinds of stimuli such as jars, a moving animal or an enemy. It is able to contract, expand, and move the tentacles in such a way as to bring food to the mouth although it does not possess nerves or a brain. When a special study of the structure of the hydra is made, nerve cells are found which assist it in responding to stimuli. In the Protozoa there are no special nerve cells but the hydra shows the beginning of the formation of a nervous system.

FIGURE 151. — PHOTOMICROGRAPH OF HYDRA BEARING EGGS ILLUSTRATING ONE FORM OF REPRODUCTION.

Reproduction by budding is shown in Figure 148.

144. Reproduction. — The hydra reproduces both sexually and asexually. In sexual reproduction eggs and sperms are produced by the ectoderm cells. The sperm cells escape into the water and, like sperm cells of all other animals, have the power of locomotion. The fusion of the egg cell and a sperm cell starts growth which results in the division of the egg cell into many other cells. Hydras also reproduce asexually by budding. The buds soon separate from the parent and begin an independent life. Like the developing sponge, the developing hydra grows until it finally becomes a fully formed hydra.

LABORATORY STUDY

The living brown or green hydras can usually be found in the spring or fall in most fresh-water ponds. They are easily collected by gathering the floating leaves and overhanging grass that is immersed in the water. Place this collection in a glass jar in the laboratory. In a couple of days the hydras will have moved from the grass to the sides of the jar. They can be examined by a small magnifying glass in the jar or be transferred to a watch glass and observed under the low power of the microscope. Watch the hydra contract, when jarred or touched. Note that the tentacles become very short. Try feeding with a small bit of raw meat. Make out the transparent ectoderm and the darker endoderm. Are there any buds? What happens to the buds when the parents contract?

FIGURE 152. — PHOTOMICROGRAPH OF THE COLONIAL HYDROID OBELIA WITH MEDUSÆ FORMING AT A.

145. Hydroids. — Hydroids are marine, hydra-like animals which are united in groups forming a tree-like colony (Figures 153, 156, *a*). They are often mistaken for plants. When the young hydroid first begins to grow, it looks like the fresh-water hydra (Figure 156, *k*).

As the hydroid grows, branches form and on the end of each branch, tentacles and a mouth appear. Each branch is able to capture food and, after it takes what it needs, the surplus is distributed to other parts. This is easily brought about, as a common digestive cavity connects all the branches. The hydroid is termed a colony because all the branches are united and help one another in getting enough food for the colony.

Some of the hydroids form curious buds which develop into *medusæ* (mē-dū′se). (See Figure 152, *A*.) As soon as the

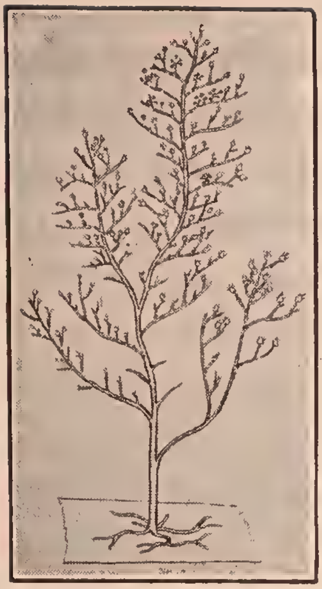

FIGURE 153. — A HYDROID COLONY.

It resembles a plant and is often mistaken for one.

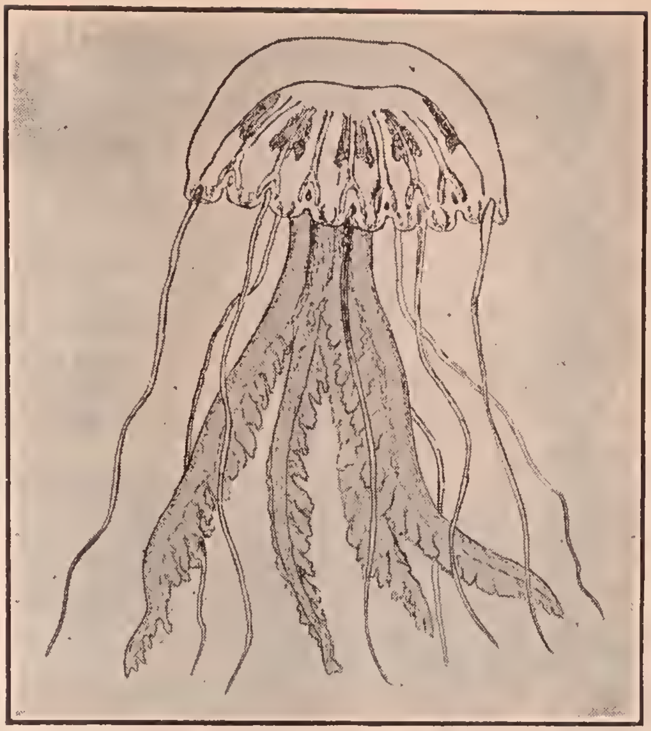

FIGURE 154. — THE MEDUSA KNOWN AS PELAGIA.

It is found swimming on the surface of the water far from land.

medusæ are set free from the hydroids, they swim about and capture their own food. Each medusa is provided with either *ovaries* (ō′vȧ-rĭz), organs which produce egg cells, or *spermaries* (spẽr′mȧ-rĭz), organs which produce sperm cells. When the eggs and sperms mature, they are discharged into the water. A single sperm cell must fuse with an egg cell before the egg can begin to grow. The union of these two cells is called *fertilization.* The egg grows into an *embryo* (ĕm′brĭ-ō), an immature stage varying with different animals, and this gradually changes into a small hydroid. The several steps

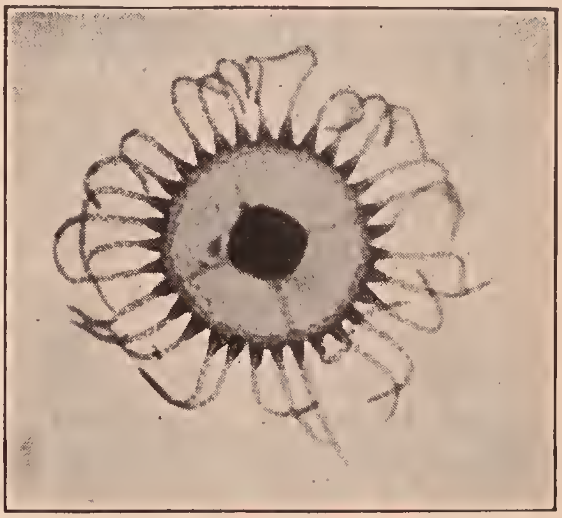

FIGURE 155.

When the medusa buds shown forming at A in Figure 152 mature, they are set free in the water and look like this photomicrograph of a free swimming medusa (greatly enlarged).

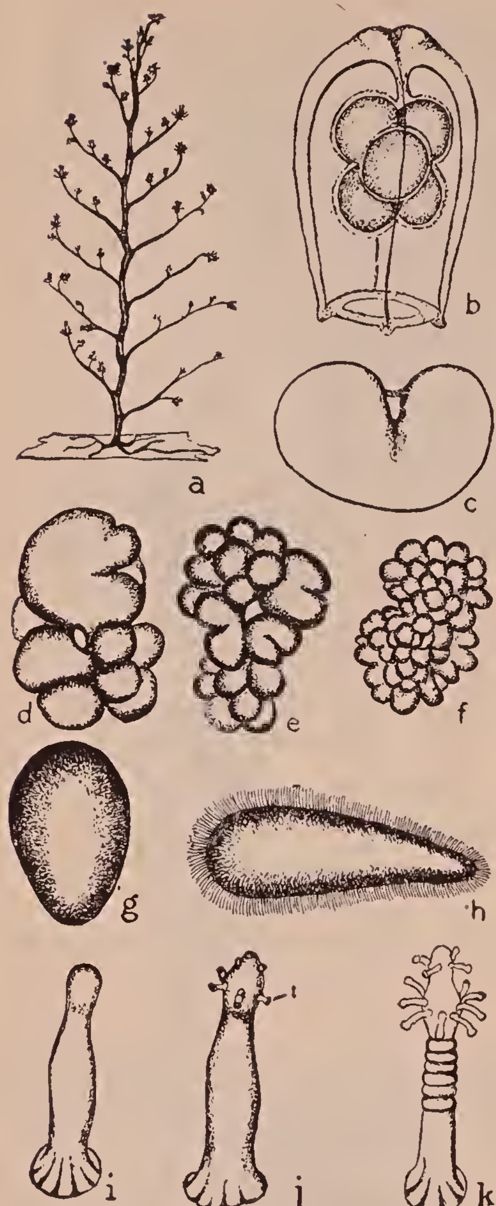

FIGURE 156. — PENNARIA TIARELLA.

a, The hydroid colony; *b*, one of the female medusæ, much enlarged; *c*, the egg of the medusa beginning to segment after it has been fertilized; *d*, *e*, *f*, further segmentation stages; *g*, the blastula stage; *h*, the free swimming larva (planula); *i*, *j*, and *k* show the gradual transformation of the larva into a hydra-like colony. Branches grow on the stage shown in *k* until a colony like *a* results. This is the form that alternation of generations takes in this hydroid. (Arranged from a monograph on Pennaria by C. W. Hargitt.)

in this complicated series of changes are illustrated in Figure 156. The hydroids and medusæ show a form of reproduction called alternation of generations, that is, they reproduce alternately sexually and then asexually.

146. Sea-anemone. — Sea-anemones are animals allied to the hydra. The interior of the body cavity is subdivided by many partitions which increase the digesting and absorbing surface. The sea-anemone reproduces by eggs and sperms.

The resulting embryo is free at first, but later becomes fixed to some object and develops into the sea-anemone. There is no medusa stage.

147. Coral. — Geographies tell us of the many coral islands and reefs built up by the coral animals. These animals are cœlenterates, most of them closely allied to the sea-anemone, but the coral animal secretes about the body and along the partitions *calcareous* (kăl-kā′rē̍-ŭs, limy) skeletons which form the stone-like masses of the coral rock. The upper portion of the coral rocks is alive

with these coral animals. The lower portion is made up of skeletons only. Succeeding generations build upon the work of their ancestors.

Corals reproduce much as trees produce branches, but at certain periods eggs and sperms are produced as in the sea-anemone. Then the embryo settles down, secretes its own skeleton, and this is added to the work of other corals.

Sea-fans and sea-plumes are cœlenterates which have the forms suggested by their names. A dried specimen of either looks as if a branch had been dipped in a solution and coated. The interior is of a horny substance. The exterior is covered with a limy secretion.

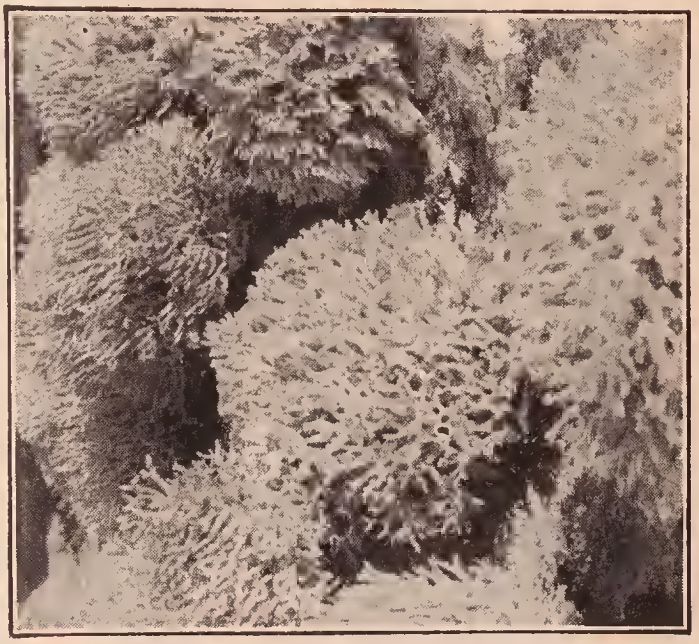

Figure 157. — Some Common Corals.

148. Economic Importance. — The corals alone of the cœlenterates are of economic importance; they add to many islands, protect others from being washed away, and in some cases form entirely new islands.

SUMMARY

The hydra-like animals represent an advance in the division of labor. The layers of their bodies are more definite and do their work better than in the sponges. Hydroids and the corals illustrate the formation of a colony. In some of the colonies the division of labor is more extensive than in others. The economic importance of some corals has been, and continues to be, very great, as they contribute to the formation of land in the ocean; on the other hand, such corals as sea-fans serve merely as odd ornaments.

QUESTIONS

Explain fully how the hydra gets its food and how some of this food finally nourishes the ectoderm cells. Compare the hydra and the hydroid. In what are they alike? In what are they different? How does the hydra reproduce? How does the hydra get its oxygen? Explain how the coral animal has been able to form islands.

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Hegner, Introduction to Zoölogy, Chapter VIII.

CHAPTER XII

THE STARFISH FAMILY

Optional

149. The Starfish Group. — This group of animals includes the well-known starfish, the sea-urchins, sea-lilies, and several soft-bodied forms such as the sea-cucumber. The technical name for these different animals is *echinoderm* (ē-kĭn′ō-dĕrm: Greek, *echinos*, spine; *derm*, skin), meaning spiny-skinned animals. Most of these animals have a skeleton. Unlike that of man it is on the outside and is composed of calcareous plates. In some forms, like the starfish, the plants are embedded in the skin, while in the sea-urchin the plates fit edge to edge, forming a shell. The plates support many spines which project out from the body giving the spiny appearance characteristic of the group. Both the skeleton and soft parts are arranged in a radial manner. The presence of spines and the radial arrangement are two characters by means of which one can recognize most of the echinoderms.

FIGURE 158. — STARFISH.

150. The Starfish. — Starfishes are found in salt water. They are composed of a central region, called a disk, from which extend five arms or rays. On the disk is a porous

circular plate. It is known as the *madreporic* plate (măd-rē-pŏr′ĭk: Greek, *mater*, mother; *poros*, soft). It serves to take water into a series of vessels by means of which the animal moves and holds on to rocks and shells at the sea bottom.

Internal Structure. — If the upper portion of the animal is removed carefully, the internal structure can be examined. Each ray is nearly filled with masses of yellowish green substance. This is a gland which forms the digestive fluids used in the stomach. The wrinkled mass in the region

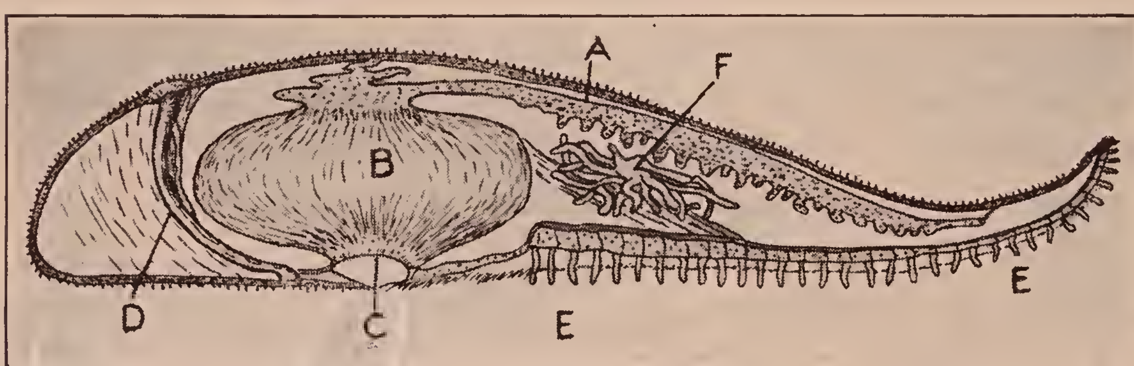

FIGURE 159. — DIAGRAM OF BODY OF STARFISH.

A, liver; B, stomach; C, mouth; D, stone canal through which the water enters that is used in the organs of locomotion; E, tube feet; F, reproductive glands.

beneath the disk is the stomach. The mouth is just below the stomach on the lower or *oral* side of the body. At the angles of the arms and extending into each ray are the reproductive glands, which vary in size at different ages and seasons. According to the sex of the individual these glands produce either eggs or sperms, which are discharged into the water.

LABORATORY STUDY

Dried specimens of starfish serve well for general study. These may be compared with specimens which have been preserved in alcohol or formalin. Work out the several parts such as disk, arms, madreporic plate, spines, groove of the feet, and position and form of the mouth. If skeletons of sea-urchins are available, they are interesting for comparison.

151. Locomotion. — Locomotion in the starfish is accomplished by means of the four rows of tube feet which extend from the rays on the oral surface. The tube feet of the arms in front are attached to the surface over which the starfish wishes to move. Then the tube feet of the arms to the rear are released and the starfish draws up these arms, raising the disk region up. The tube feet in the arms to the rear are attached to the surface while the arms to the front are released and pushed ahead as the disk is lowered to the surface. This motion is carried on slowly until the starfish has reached its destination. Each tube foot has an adhesive disk and is connected with a small reservoir inside of the arm.

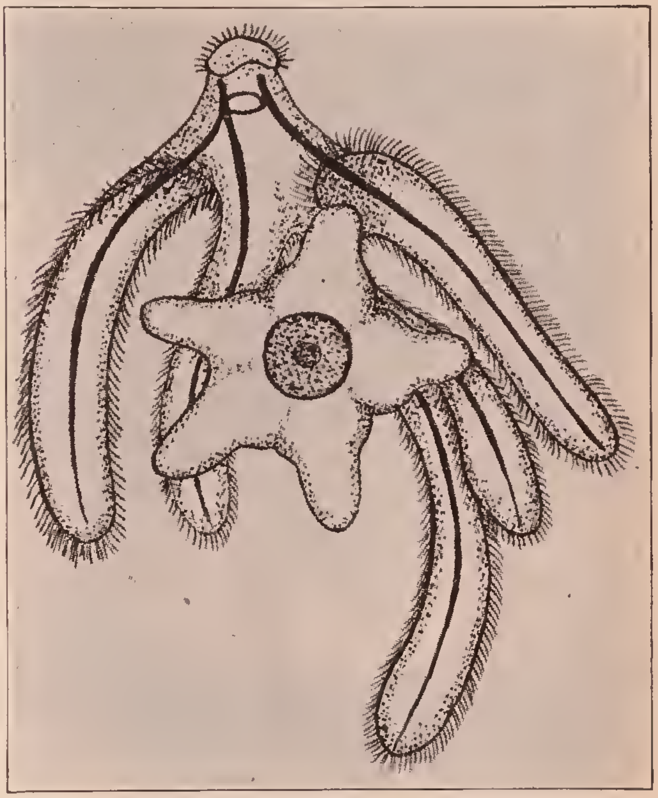

FIGURE 160. — THE EMBRYO OF THE STARFISH.

It develops into a free swimming larva that does not look at all like the parent. After a time the young starfish is formed.

152. Food Taking and Nutrition. — The starfish takes its food in an unusual manner. Most animals move the food to the mouth, swallow it or engulf it, and digest it within the body cavity. In the case of the starfish we find that the stomach is projected through the mouth and made to surround its food. In this position it digests and assimilates the food and then withdraws its stomach through the mouth and moves on slowly to some other place. A common food of the starfish is the clam. Various explanations have been offered as to how the starfish is able to secure the soft flesh

of a clam or oyster which is protected by hard shells. It is now known that the starfish attaches its tube feet to each side of the clam and by constantly pulling tires out the strong muscles that hold the shell together. As soon as these muscles relax, the shell opens. The stomach is then pushed out, enveloping the clam. The digestive fluid containing enzymes is secreted and the dissolved clam is absorbed as food.

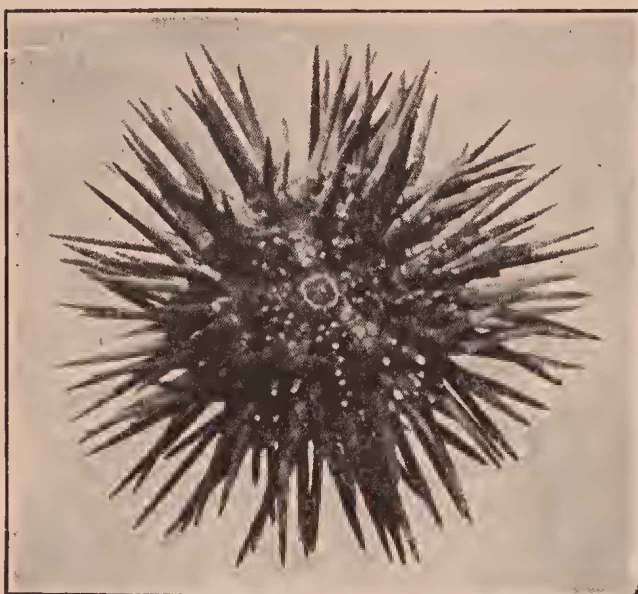

FIGURE 161. — PURPLE SEA-URCHIN.
The long spines serve as a protection.

153. Respiration. — Oxygen is taken from the water and carbon dioxide given off through little thin-walled, gill-like processes which cover the upper surface of the disk and arms. These gill-like processes project through holes in the exoskeleton.

154. Excretion. — There are no special organs in the starfish for the removal of wastes.

155. Nervous System. — The starfish possesses a definite arrangement of nerves. In this respect, it shows a marked advance over the hydra. There are five nerves, one in each arm, all of which join a nerve collar that surrounds the mouth. There is no brain. This nervous system of five nerves and a nerve ring receives stimuli and controls the slowly contracting muscles.

156. Life History of the Starfish. — In the starfish the sexes are distinct. The female discharges eggs into the water and the male discharges sperm cells into the water. The sperms being constantly in motion, are likely to meet the eggs. When this occurs, a sperm cell enters an egg,

starting the growth and development of the starfish larva. The larva is at first wholly unlike the starfish in form; there is not even a suggestion of the starfish outline. After the larva has attained a certain size a tiny bud appears which develops into the little starfish. The bud develops on the larva and feeds on it. From this bud the adult starfish develops. This is another example of metamorphosis (Figure 160).

FIGURE 162. — THE COMMON SEA-CUCUMBER.

An Echinoderm without any skeleton for protection. It has become adapted to living in the sand much like the worms.

157. Other Echinoderms. — The sea-urchins are thickly covered with spines and have tube feet which, in many cases, may be greatly extended. When the spines are removed, an exoskeleton is revealed, which plainly shows the radial arrangement characteristic of the echinoderm group.

158. Economic Importance of the Group. — Of echinoderms the starfish alone has an economic bearing. It is harmful. Living as it does in the region of the oyster and clam beds and feeding almost exclusively on them, the starfish annually destroys thousands of dollars' worth of clams and oysters. By removing the seaweed where the immature starfish gather and by dragging the oyster and clam beds great numbers of starfish are destroyed.

In former times the fishermen used to break starfish to pieces on the side of the boat and throw them back into the water. It is now known that by so doing they were but increasing the number of starfish, for starfish have the power to re-grow the parts broken off. Each complete arm could reproduce an entire starfish. This power to restore lost parts is known as *regeneration* (rē-jĕn-ẽr-ā′shun). Many of the lower animals have this power to a marked degree, and all animals have it to some degree.

SUMMARY

The starfish group of animals is known by the presence of spines in the skin and a radial arrangement of the organs. Their chief economic relation to man consists in their great destructiveness to oyster and clam beds.

QUESTIONS

Why are starfish so called? How can they be distinguished from other animals? How do they move? Where do they live? On what do they feed? How do they secure oxygen?

REFERENCES

Brooks, The Oyster.
Osborne, Economic Zoölogy, Chapter VIII.
Poulton, All About the Oyster.

CHAPTER XIII

THE WORM GROUP

159. The Worm Group. — Here are found several distinct groups of animals that in advanced text-books of zoölogy are treated separately. The word "worm" is an old term which properly describes such animals as the earthworm, sea-worm, leech, tapeworm, flatworm, and a few others. The word "worm" cannot be correctly used for such larvæ of insects as the "apple tree worm" or "currant worm."

The worm group is divided into two classes: those whose body is composed of numerous *segments* (sĕg′mĕnts) or rings, such as the earthworm, the sea-worm, and the leech; and those whose body is not segmented, such as the tapeworm and flatworm. The first class comprises the true worms, which are known as *Annelida* (ă-nĕl′ĭ-da). The second class, the unsegmented worms, have no single technical name, and are not believed by scientists to be true worms. They comprise a number of worm-like animals which have hardly any features in common. Here are found the fresh-water planarians, the parasitic tapeworms, liver flukes, and numerous round worms, of which the hair worm is an example.

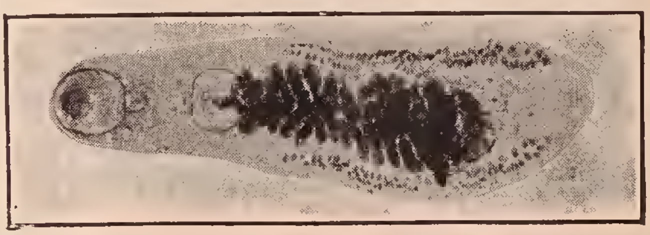

FIGURE 163. — A PLANARIAN WORM.

These fresh-water worms are abundant during the summer and are easily collected for class study.

The planarian worm is one of the simplest of these unsegmented worms. It is found under stones submerged

in stagnant water and in streams. It is frequently brought into the laboratory and can easily be kept alive in aquaria.

The liver fluke is a parasitic flatworm which each year causes the death of many sheep by injuring their livers.[1] Like some other parasitic animals the liver fluke requires two hosts to complete its development. The hosts of the fluke are the sheep and certain snails. The adult liver flukes form eggs and sperms in the liver of the sheep. The fertilized eggs partially develop in the sheep; then as embryos they pass down the bile duct into the intestine and then out of the body.

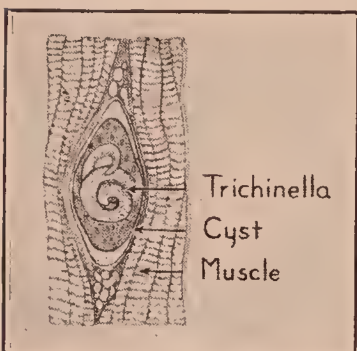

FIGURE 164. — TRICHINELLA.

A picture of this parasitic worm in the muscles of man. Note the membranous sac which encloses it. This is the form of the sac after the worm comes to rest in the muscles. The worm is then said to be encysted.

The *ciliated* (sil′i-a-ted) larva then makes its way into water or along dew-covered grass. If it comes in contact with a water snail in the water or a land snail on the grass, it enters the body of its second host, otherwise it dies. Once inside the body of the snail it completes a complicated development. By a bud-like process many young flukes are formed which finally emerge from the snail and make their way to the grass stems on which they encyst themselves. If this grass is eaten by a sheep, the digestive fluids set free the young fluke, which goes up the bile ducts to the liver, where it grows to maturity.

160. Trichina. — Another unsegmented worm that is of economic importance is the Trichina (trĭ-kī′na), now generally called Trichinella (trĭ′kī-nĕl′la). This worm lives in the intestine of mammals and from the intestine migrates into the muscles of its host. In the muscle it becomes encysted and remains until the flesh is eaten by some other

[1] The Animal Parasites of Sheep. Dr. Cooper Curtice. Bureau Animal Industry, United States Department of Agriculture, 1890.

mammal. When pork, infected with this parasite and insufficiently cooked, is eaten by man the cysts are dissolved by the digestive fluids and the worms are freed.

These worms then develop eggs and sperms which after uniting mature into young worms and migrate through the intestine into the muscles. The activity of the worms at this stage causes a serious inflammation of the tissues and a disease known as trichinosis (trĭk-ĭn-ō′sis), which is often fatal. Hogs contract trichinosis by eating refuse that contains the encysted worms.

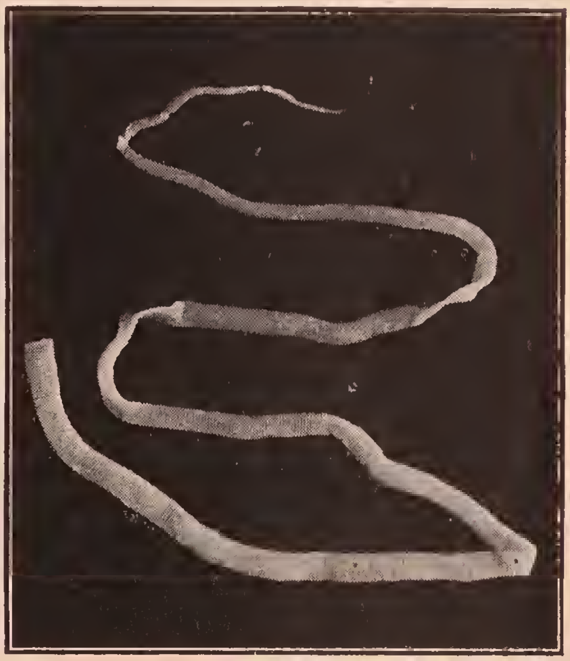

FIGURE 165. — A COMMON TAPEWORM.
Taken from the intestine of a dog. This worm is thin and ribbon-like.

Government inspectors examine pork which is to be exported or sold in large quantities to see that it is free from these parasites. The smaller sales of pork by local dealers are not inspected and the only way to be sure of the harmlessness of the meat is to cook it thoroughly.

Hair Worm. — The only importance that can be attached to these worms is the myth about their origin. In almost every school will be found students who believe that horse hairs placed in water will develop into "hair snakes." It would be a pity if a student still believed this after a course in biology.

Let us see how such a belief can originate and often be thought to be proved. The hair snakes live for a time in water and often in the watering troughs where horse hairs are also found. Boys, and men too, sometimes put horse hairs in water and then after a few weeks examine the water and find these hair snakes. They conclude, since they put in the

hairs and later found the "hair snakes," that the hairs grew to form the snakes or small round worms. If they had been as careful to look before any hairs were put in, they would have seen these "hair snakes" swimming about. A better test is to take a bottle of distilled water, put in the hairs, and watch for developments. Such a test would show that no hairs turn into hair snakes.

Hair snakes have a complete life history as clearly defined as other worms. They lay eggs which fuse with sperms and form larvæ. These larvæ live as parasites in the bodies of insects and fishes and when mature make their way out

FIGURE 166. — HAIR WORM LIVING AS A PARASITE IN THE BODY OF THE GRASSHOPPER.

of the bodies of their hosts. It would be natural, then, to find them in pools where horses drink and these parasitized fishes live, or in watering troughs into which grasshoppers may have jumped, as they so often do.

We know at present no way in which lifeless matter can be made to live. A hair cannot become a worm and a crooked stick cannot grow into a snake. New life comes from the old. We sometimes read in the papers that some one has produced life from chemicals, but it is not believed at the present time to be possible.

161. The Earthworm is the simplest and best animal to illustrate the annelid group of true worms.

When one examines a living earthworm, the head end

can be determined as the one which first moves forward. Actually there is no head; nor are there special sense organs. The muscles in the front end are stronger and the body rounder than in the back end. The back, or *dorsal* (dôr′s’l) part, of the worm which is exposed to the light is darker in color than the rest. This surface is rounder than the opposite (under) one which is in constant touch with the dirt when the worm is crawling. The flat surface upon which the worm crawls is the *ventral* (vĕn′tral) surface.

The body of the earthworm is made up of a number of segments (rings) which are marked off by shallow grooves. Some of the segments in the front end are larger than those that make up the back end, but all are similar in shape. The number of segments depends mostly upon the age of the earthworm. It is from 60 to 150 in full-grown worms.

162. Locomotion. — The earthworm crawls by means of short, stiff bristles used as legs, the *setæ* (sē′tē: Latin, *seta*, bristle), which are found in all the segments except the first two or three. These setæ are arranged in four rows, two in each row. To understand how the setæ are used in the locomotion of the earthworm it is necessary to know that the body wall contains two muscular layers. In the outer layer the muscles running around the body are called circular muscles. The inner layer, consisting of a number of bands running in the direction of the length of the body, are called longitudinal muscles. The contraction of the circular muscles lengthens the body and the contraction of the longitudinal muscles shortens it. The setæ are connected with the longitudinal muscles. By pointing the setæ backward and bracing them against the ground, the worm can push itself forward. By pointing the setæ forward the worm can instantly change the direction of its movement. This is the reason why it is so difficult for a robin to pull an earthworm from its burrow. Often the robin will tear the worm apart, so firmly do these setæ hold.

LABORATORY STUDY

One of the annelids should be studied with some care, as an illustration of an invertebrate animal. How do you determine the anterior and posterior ends? Dorsal and ventral surfaces? The number of segments? Compare several worms. The back region of the worm shows the most variation because new segments are being added. Where are the setæ? How does the earthworm move? Place it on a glass. The front region of the body is most sensitive to touch. Test it.

163. Food-taking. — The food of the earthworm is chiefly the soil in which it burrows. By means of an upper lip, which is a specialized anterior segment, and the muscular walls of the pharynx it takes the earth into its body, and the muscles of the digestive tube advance the food along its course. The soluble and therefore digestible parts are absorbed, and the remainder (the greater portion) is passed along to the outside. Earthworms are not critical in the selection of their food, although they are not entirely without a sense of taste.

164. Respiration. — Oxygen passes through the skin directly into the blood vessels. The blood carries the oxygen to all parts of the body. Carbon dioxide passes from the blood through the skin to the outside. This interchange of oxygen and carbon dioxide is brought about by osmosis.

165. Excretion. — In each segment is found a pair of organs known as nephridia which look like little threads. These organs remove the liquid waste and carry it to the outside of the body.

166. Internal Structure of Earthworms. — This is shown diagrammatically in Figure 167. The internal structure consists of an outer tube, the body-wall, and an inner tube, the digestive tube. The space between the body-wall and digestive tube is known as the body cavity or *cœlome* (sē′lŭm: Greek, *koilos*, hollow). Thin sheets of membrane pass from each furrow between the segments to the digestive tube.

Beginning at the front end the digestive tube is given

certain names for each distinct region, as follows: the *mouth cavity;* the *pharynx* (făr′ĭnks), with its thick muscular walls; the *esophagus* (ē-sŏf′a-gŭs), thin-walled and small; the *crop,* a wide pouch; the *gizzard,* where food is ground; and the *stomach-intestine,* a large, thin-walled tract extending through the last two thirds of the length of the worm.

The earthworm has an easily recognized nervous system which is found beneath the digestive tube. It consists of a continuous, minute, white thread with slight swellings in each segment. From these swellings, which are called

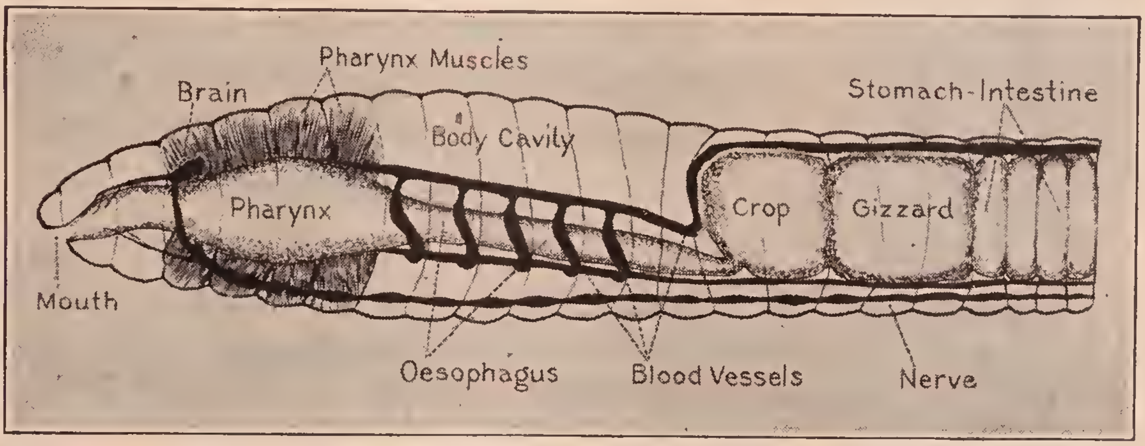

FIGURE 167. — THE ORGANS OF THE EARTHWORM.
Drawn from the side. (Esophagus also spelled œsophagus.)

ganglia (găn′glĭ-ȧ: Greek, *ganglion,* swelling or tumor), short branches extend to the digestive tube and other organs. These branches are known as nerves. Toward the front end the nerve-thread parts and becomes double. Each part passes around the front end of the pharynx and enlarges to form two ganglia, the largest found in the earthworm. More nerves grow from these two large ganglia than from any of the others and so the term " brain " is given to these two ganglia found in the dorsal surface of the pharynx (Figure 167).

The nervous system of the earthworm is clearly defined and occupies a central position, being found in the middle of the body. Although they have no eyes or ears, earthworms

are able to tell the difference between night and day and to withdraw into their burrows if one steps heavily on the ground near them or takes a small stick and strikes the ground within a few feet of them.

The organs of the earthworm are supplied with blood which is carried in a large dorsal blood vessel, a ventral blood vessel, and numerous branches. The blood is pumped by the contracting of the dorsal vessel and by the five pairs of tubes which pass from the dorsal to the ventral vessel around the esophagus. These five tubes are named *aortic* (ȧ-ôr′tĭk) arches.

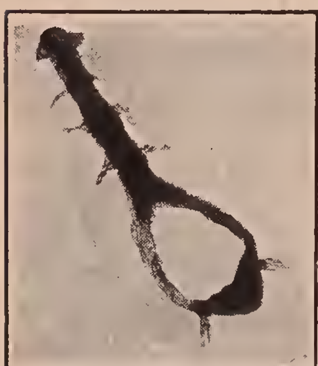

FIGURE 168. — FRONT END OF THE NERVOUS SYSTEM OF THE EARTHWORM.

The large mass is termed the "brain" because of its size and position.

LABORATORY STUDY OF INTERNAL STRUCTURE

Work out the internal structure of the earthworm. In dissecting, cut the skin along the dorsal surface, being careful to cut the many membranes that hold the digestive tube in place. Work out the size and position of the mouth cavity, pharynx, esophagus, crop, gizzard, and stomach-intestine. The white reproductive organs are located beside the esophagus. Locate the "brain," the ventral chain of ganglia. The dorsal blood vessels and aortic arches should be located. Make a sketch locating the organs in their respective segments.

167. Life History. — In the starfish group the sexes are distinct. The sexes in the annelids are distinct in some forms and in others the same individuals have both ovaries and spermaries. The sperms, however, that unite with eggs always come from another worm. During the season when the ovaries and spermaries are forming eggs and sperms, certain segments, usually six in number, beginning with the twenty-eighth segment, and known as the *clitellum* (klĭ-tĕl′lŭm), pour out a gelatinous secretion which hardens into a collar-like sac around the worm.

This sac is worked forward and as it passes the openings of the reproductive organs, eggs and the sperms from another worm are pushed into it. The sac continues to move forward and finally leaves the worm as a closed capsule. This capsule contains eggs, sperms, and fluid food. After the fusion of the eggs and sperms, the resulting embryonic worms begin to feed upon the fluid food in the capsule; later they feed upon one another until but one may remain eventually to bore or eat its way to the earth outside. From now on the food of the young worm is the soil.

The earthworm is an example of an animal which has both ovaries and spermaries.

168. Self-protection. — The habit earthworms have of remaining in their burrows during the daytime is their chief means of protection. During the daytime birds and other animals seek them out as food. They are perfectly helpless when captured. When a robin tries to pull an earthworm from its burrow, the projecting setæ prevent the worm from being pulled out. Sometimes the body breaks under the strain but this does not kill the worm as the portion remaining in the burrow soon regrows the lost parts. During the winter or a dry season earthworms burrow deep into the ground and collect in groups for protection.

FIGURE 169. — DERO, A COMMON FRESH-WATER ANNELID.

169. Economic Importance. — The value of earthworms to agriculture is too great to be overestimated. In burrowing their way through the soil they leave passageways for water and air to enter, thus assisting plants to grow. They bring the fertile, swallowed soil to the surface. When the total number of earthworms is considered, it is obvious that they are the great natural cultivators of the soil.

170. Other Annelids. — The sand worm or *Nereis* (nē′-rê-ĭs), a marine or salt-water form, is another segmented annelid. It is more highly specialized than the earthworm, for it has biting mouth parts, tentacles, and eyes. It is an active swimmer at times. The development of the sand worm exhibits metamorphosis, while the earthworm hatches directly into a worm without metamorphosis.

SUMMARY

In the worm group are included the unsegmented worms, such as tapeworms, liver flukes, and hair worms; and the segmented or true worms such as the earthworms, sea-worms, and leeches. All these worms have more perfectly organized parts than the sponges and hydroids. The body of the earthworm shows the first steps in the formation of definite front, back, and ventral regions. The digestive tube is also specialized into pharynx, esophagus, crop, gizzard, and stomach-intestine; and the name *brain* may be given to a slightly enlarged portion of the anterior end of the nerve cord. Small worms of various kinds are numerous in stagnant water. Some live as parasites in man and other animals, causing much suffering and loss of life. The earthworm as a cultivator of the soil has been of inestimable value to man.

QUESTIONS

What kinds of animals are called worms? Is it proper to call "currant worms" worms? Why not? What are they? How do you recognize the anterior, posterior, dorsal, and ventral regions? Compare the grasshopper or some other insect with the worm. Explain how the earthworm moves; makes its burrow. Compare the digestive tube with the digestive sac of the hydra.

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Jordan, Kellogg, and Heath, Animal Studies, Chapter VI.
Sedgwick and Wilson, General Biology.

CHAPTER XIV

THE MOLLUSKS

171. The Mollusks. — This group includes such animals as clams, oysters, snails, slugs, squids (skwĭds), and octopi (ŏk′tọ̄-pī). These forms differ from the crustaceans in having a soft, unsegmented body and, in most cases, a shell as their exoskeleton. The squids have a shell that is internal, and in some of the snails the shell is absent.

FIGURE 170. — CLAM SHOWING FOOT.

Water enters through i.s., inhalent siphon, and leaves the body of the clam through e.s., exhalent siphon.

172. Clams. — The fresh-water clam is a convenient type of mollusk to study. It is found in canals and in many streams and lakes. This clam has two shells or valves and, when moving naturally, the hinge is uppermost, while the opened valves allow the foot to be extended into the mud. The foot is a thick, muscular mass, not at all foot-like in appearance, but it enables the clam to move, although slowly and at an uneven rate.

Structure. — The structure of the fresh-water clam shows how it has adapted itself to its peculiar method of life. The shell is lined with a membrane called the *mantle.* The mantle secretes the shell-material and adds to its size year by year. At the back, the edges of the mantle are united at three points, thus forming two openings known as *siphons* (sī′fŏns). Through one of these siphons water

enters, carrying food and oxygen. Through the other the water passes out, carrying the waste from the body.

Between the mantle and the body proper are four gills, which hang free in the shell cavity. The gills are filled with holes through which water passes.

The foot, which is attached directly to the body proper, is that part of the clam hard to chew when it is eaten. The foot and body form a solid mass that nearly fills the space between the shells.

The two valves of the clam shell are held together by means of strong muscles, attached to each shell. One of these, located in front of the body, is known as the *anterior* (*front*) *adductor* (ăd-dŭk′tẽr) muscle; the second is just back of the body and is the *posterior* (*back*) *adductor* muscle. When these two muscles contract, the two valves are held tightly together. Before the live clam can be examined these two muscles have to be cut, as it closes its valves when handled. When the clam is dead, these muscles relax and the hinge forces the valves apart. It is not safe to eat clams and oysters that have died in their shells.

Figure 171. — Left Shell of Clam.

Showing mantle and muscles. a.a., anterior adductor muscle; p.a., posterior adductor muscle.

When the two adductor muscles are cut free from the valves, a round or oval surface is seen which is marked off from the rest of the interior of the shell. These areas are called muscle scars (Figure 171).

When the empty clam shell is examined, it is found that the hinge, sometimes called the hinge ligament, is elastic. This is shown by compressing the two valves and seeing how promptly they open when the pressure is taken off. Where the two valves come in contact just beneath

the hinge ligament, a blunt projection of one shell fits into a depression in the other. These are called the hinge teeth.

LABORATORY STUDY

Live clams can be secured in the market during the school year. The dissection of the clam is too difficult, but the arrangement of the organs in the mantle cavity can be studied. The position of the adductor muscles, foot, gills, palps, heart, etc., should be observed. Examine a small portion of a gill under the microscope for cilia. A variety of shells of clams should be studied in which hinge, muscle scars, and hinge teeth are examined. Compare clam and snail shells.

Digestive System. — The mouth, which is located under the anterior adductor muscle, leads through the short esophagus to the stomach. The intestine winds through the foot region forming a loop, finally ascending and passing through the pericardium and between the chambers of the heart itself and opening into the upper siphon (Figure 172).

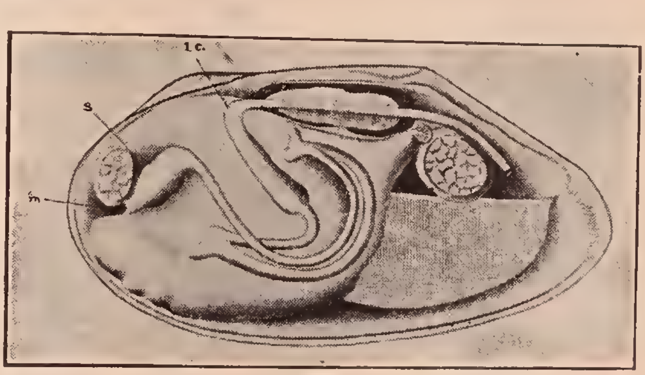

FIGURE 172. — DIGESTIVE TUBE OF CLAM. m, mouth; s, stomach; i.c., intestine.

Circulation is well developed.[1] From the heart colorless blood is carried through arteries into smaller tubes, and returns, through veins, back to the heart.

173. Locomotion. — The movements of the fresh-water mollusks are extremely slow. In the clam the foot is forced out of the shell by the blood, which flows into it and causes the foot to be greatly enlarged. Muscles attached to the shell and front of the foot contract and pull the shell forward over the extended foot.

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[1] The three-chambered heart lies in the dorsal region, near the hinge, in a little soft-walled chamber, the *pericardium* (pĕr-i-kär′di-um: Greek *peri*, around; *cardia*, heart).

174. Food. — The food of the clam consists of microscopic plants and animals that are caught in a sticky fluid (*mucus*) on the gills, as the water passes through them. The food, together with the mucus, is moved into the mouth by means of cilia. The mouth is simply an opening into the body and the cilia are on triangular flaps or lips (palps) on either side of the mouth. From the mouth food passes into the digestive canal, where the nutritious parts are absorbed (Figure 172).

175. Respiration. — The clam, like other aquatic animals, gains its oxygen from the water and gives off carbon dioxide. A close inspection of the mantle shows the presence of blood vessels which are more numerous than in the gills. For this reason, the mantle is regarded as the main organ of respiration, although the gills also assist.

FIGURE 173. — EMBRYO OF CLAM.

At this stage it becomes attached to the gills or fins of a fish. Here it remains for some weeks, gradually transforming into a clam.

176. Excretion. — The wastes of the body are absorbed by the kidneys and passed out into the water through the upper siphon.

177. The Nervous System is not so well developed as in the crayfish. There are three groups of ganglia (nerve cells). One located far back in the body near the posterior adductor is called the visceral ganglion because it largely regulates the activities of the *viscera* (vĭs′sê-rȧ), the internal organs of the body. Another in the foot region is called the *pedal* (pē′dal) ganglion, and regulates the movements of the foot. A third located in the region of the gullet (esophagus) is the cerebral ganglion, which regulates the activities of the part near the mouth. All these are connected by nerves.

178. Life History. — In clams the sexes are distinct. Eggs formed in the ovaries of the female fuse with sperm

cells from the males taken in with the water through the siphon. These sperm cells have reached the water through the upper siphon. Thousands of embryos form in the body of the female and develop into larvæ in the outer gills, which thus become greatly distended. Later the larvæ pass into the water through the upper siphon.

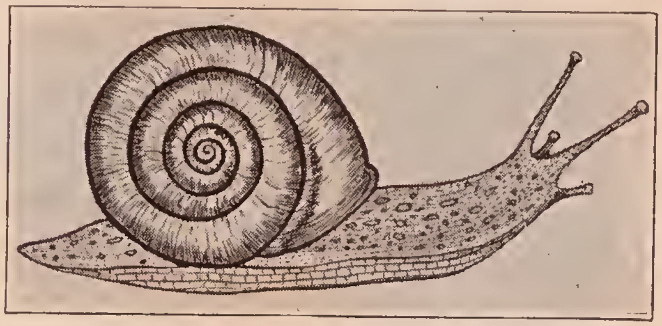

FIGURE 174. — SNAIL.

Notice the relation of the animal to its shell. The eyes are borne on the ends of the tentacles on the top of the head.

The larvæ of many fresh-water clams have hooks on their shells by means of which they are able to cling to the gills or body of a fish, where they live as parasites for several weeks. They absorb food from their host and are carried from one place to another and are thus scattered. After a few weeks they leave the host and settle down to lead an independent life.

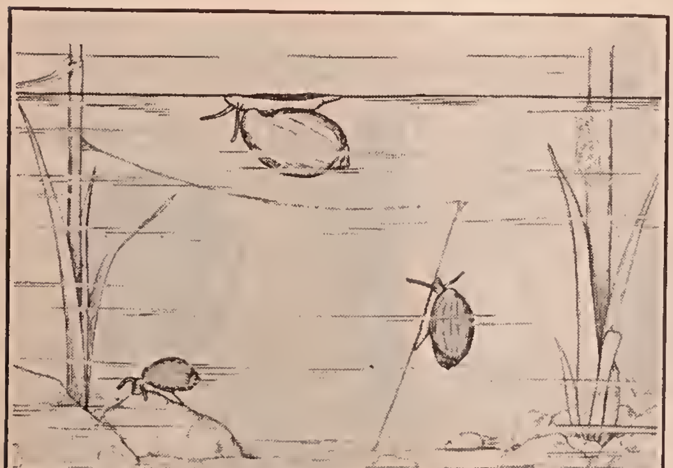

FIGURE 175. — OUR COMMON POND SNAIL.

Notice that they are able to creep along the surface of the water like a fly walking on the ceiling. They also have special paths running in various directions through the water. These paths are made of slime that the snail gives off. There is a mass of eggs attached to one of the plants. These eggs are orange color and deposited in a mass of jelly.

179. Snails. — Snails, having one valve, are called *univalves* as distinguished from clams, oysters, etc., which are called *bivalves* because their shells are formed of two valves. The greater number of snails are marine (live in salt water), although some live in fresh water and some on land. Snails have a broad foot which is used as a

creeping disk. There is a head region provided with eyes and tentacles. The mouth of the snail is provided with a rasping structure known as the *lingual ribbon* (lĭn′gwal: Latin, *lingua*, tongue) by means of which it is able to cut and bore its way, even through rocks. Land snails by osmosis get oxygen from the air through the mantle, while water snails use gills and take their oxygen from the water.

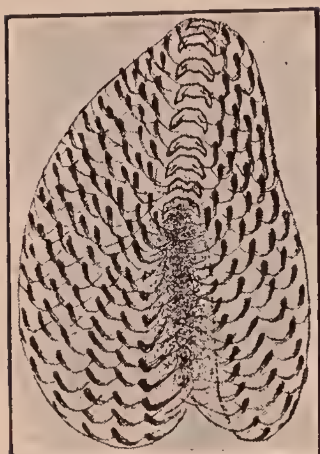

Figure 176. — Lingual Ribbon of a Snail (greatly enlarged).

In the garden slug the shell when present is thin and affords small protection.

180. Pond Snail. — The pond snail, known by the scientific name of Physa, is very common in fresh-water ponds, where it lives among the water plants. It moves about by means of muscular movements in its broad foot. It is interesting to observe Physa from beneath as it creeps over the surface of glass and to note these contraction waves. As it moves through the water a trail of slime is left behind. If these snails are studied in a jar of water, some will be seen creeping along the surface, some slowly sinking to the bottom and others creeping up slime threads (Figure 175).

Figure 177. — Snail Shells.

The pond snails live almost entirely on plants. Most of these plants are caught in the slime threads and both are

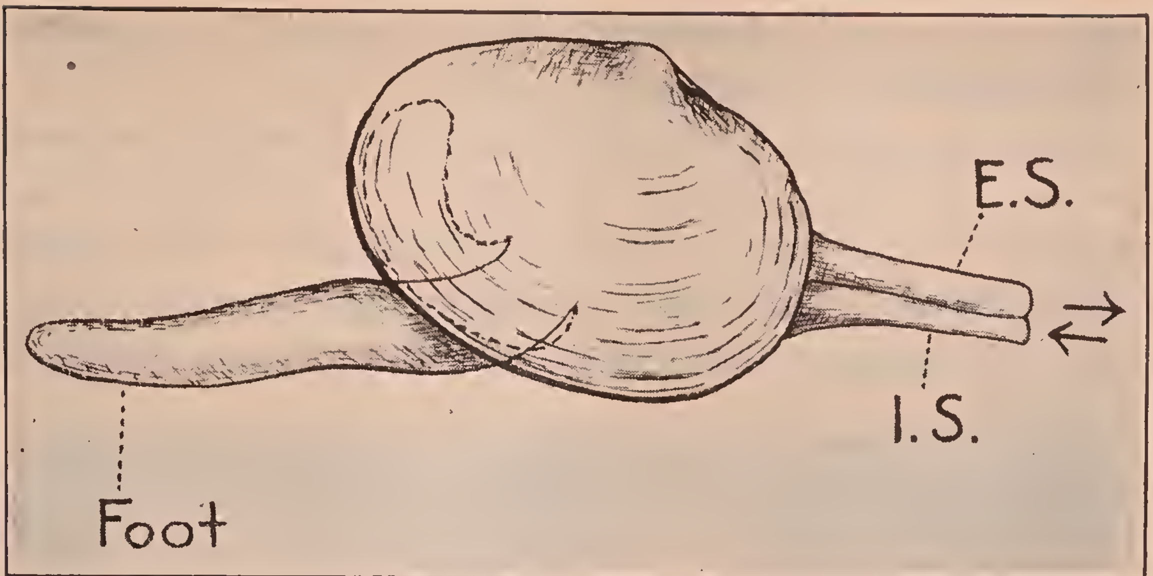

FIGURE 178. — SOFT-SHELLED CLAM.
Much prized as food. I.S., incurrent siphon ; E.S., excurrent siphon.
Note the clam's foot.

then eaten. Snails also gnaw away the surface of the water plants with their rasp-like tongue (Figure 176).

These snails lay eggs in jelly-like masses that stick to the leaves of plants. The jelly-mass protects the developing embryos and furnishes food to the young snails. As soon as the young of Physa are fully formed they escape from the jelly-mass and are able to care for themselves.

FIGURE 179. — AN OCTOPUS OR DEVIL-FISH.

181. Squids, Cuttle Fish, and Octopi belong to the *Cephalopods* (sĕf′à-lō-pŏds: Greek, *kephale*, head; *pod*, foot), the highest division of the mollusks. The nervous system is highly developed. The eye of the squid in particular is complex and more like the eye of vertebrates than of any

animal thus far considered. The mouth of cephalopods is surrounded with tentacles.

A common squid, *Sepia* (sē′pĭ-a), has ten arms or tentacles, two long and eight short. It moves itself forward rapidly by shooting out water from a siphon in the collar region. When pursued, the squid ejects an ink-like fluid which clouds the water, concealing it from its prey and facilitating its escape.

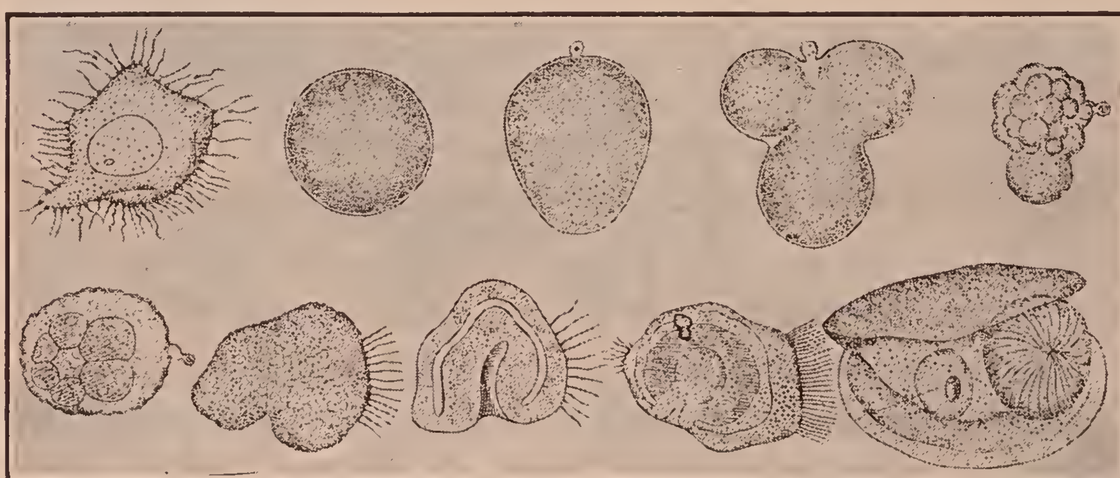

FIGURE 180. — STAGES IN THE LIFE HISTORY OF THE OYSTER.
It, like all other animals, begins as a single cell.

Cuttle fishes are similar to squids, the marked differences being in the shape of fins, the form of the eyes, and the shape of the longer tentacles.

The octopi are the largest members of the group. They have eight tentacles, which in some cases reach a length of thirty feet. The stories about the size and behavior of the octopi are often exaggerated.

182. Economic Importance of the Group. — Clams, scallops, oysters, and snails are used as food in all parts of the world. In this country, oysters are gathered in great abundance from Chesapeake Bay and other bays along the Atlantic Coast.

The edible clams are of two kinds. The round clam, *Venus mercenaria* (Vē′nŭs mĕr-sē-nā′rĭ-ȧ), is more generally

used as food, but the soft-shelled clam, *Mya arenaria* (mī′ȧ ăr-ĕn-ā′rĭ-ȧ), is eaten extensively near the seashore. The soft-shelled clam has a long siphon which may be extended several inches beyond the valves (Figure 178).

The *scallop* (skŏl′lŭp) is another mollusk that is eaten near the shore more extensively than elsewhere. This mollusk has but one adductor muscle, which is the edible portion.

FIGURE 181. — BARNACLES AND CLAMS GROWING ON OYSTERS.

Clams and oysters are raised artificially and regularly planted on natural feeding grounds. Care is taken to have such natural enemies as the starfish removed, and, in the case of oysters, brush and shell are added that they may fasten to these rather than sink to the bottom, where they become covered with mud.

The culture of oysters and clams near the mouths of rivers contaminated with sewage is unsanitary, and disease may be caused by eating such mollusks raw. This is one reason for the laws regulating the disposal of sewage, and for government inspection of the feeding grounds.

SUMMARY

The parts of mollusks are not arranged in segments like the earthworms or crustaceans. The usual presence of a shell and mantle and the fact that the soft body is not divided into segments helps to distinguish a mollusk from any other animal. The microscopic food of the clam is caught in the mucus and carried by cilia to the mouth. The clams and oysters are valuable for food but should not be eaten if taken from water contaminated by disease germs. Mollusk beds should be protected from such contamination.

QUESTIONS

What are some of the common mollusks? Where do they live? How do they get their food? What ones are used for food by man?

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PART II

PLANT BIOLOGY

CHAPTER XV

THE LIFE OF FLOWERING PLANTS

183. Introduction. — The plants that we all know and admire best are those that at some time in their lives produce beautiful flowers. These flowers, however, are only temporary structures which drop off as soon as their work is done. They are the special adaptations of the plant for producing more plants. The parts of the plant which have to do with its own life and well-being have adaptations too, many of which are as interesting as the flowers.

These parts of a plant may be divided into two groups: those that are adapted to doing their work in the air, such as the leaves and the stem, and those which do their work in the soil, such as the roots and root hairs. In studying these parts of some of our familiar plants we shall give most attention to those structures which require explanation as to how each does its share in helping the whole plant to live.

All these structures, the flower, the leaves, the stem, and the roots, are common to most plants. Each structure assumes its part in carrying on the life processes of the plant which could not live successfully without them all. A plant is an organism, and its several parts are organs or groups of organs (page 7).

We thus begin our study of plants with their special adaptation for their work which is just the way that we began our study of animals.

In our study of flowering plants we can begin with any organ or with any stage in their life history. Many persons begin with the seed. In this book we shall begin with the flower.

If the study of plants is begun in the fall, the nasturtium flower offers a good example of adaptations. You will notice that it has (1) a striking color in contrast with the foliage. This enables insects to see it readily. (2) It has an odor. This enables insects that are guided largely by the sense of smell to find it. (3) It has a long nectar spur on one side of the flower. This attracts the larger insects for the food they can get. (4) The lower petals have an inner fringe which retards the crawling insects that are trying to get the nectar. (5) The upper petals project over the other parts of the flower. This keeps the rain from running down the nectar spur and prevents the pollen from becoming wet. (6) The lower petals have stripes that lead to the opening of the nectar spur. This indicates the direction that insects should travel to find the opening quickly. (7) The anthers mature at different times. This insures a supply of pollen on different days so that some of the pollen is in condition to use, even if some has been spoiled by unfavorable weather. (8) The anthers and stigma mature at different times so that the pollen cannot get on its own stigma. This ensures hardier seeds by preventing inbreeding. There are at least eight ways in which the nasturtium flower is adapted to the visits of insects and to the protection of its pollen and nectar. There are many other aspects of the study of flowers as interesting as the study of adaptation, some of which will be mentioned later.

LABORATORY STUDY OF A NASTURTIUM

Provide each pupil with a nasturtium flower.

Draw the flower, and label the parts as follows: (1) *sepals*, the outermost, greenish parts; (2) *petals*, the colored, larger parts; (3) *stamens*,

Charles Edwin Bessey was born in Milton Township, Wayne County, Ohio, May 21, 1845, and died at Lincoln, Nebraska, February 25, 1912.

He was educated in the country schools and academy, and at the Michigan Agricultural College, from which he graduated in 1869. In February, 1870, he began his duties as Professor of Botany at the Iowa State College at Ames, Iowa. In addition to botany, he taught zoölogy and entomology for the larger portion of the fifteen years that he remained at that institution. He assumed the professorship of botany at the University of Nebraska in November, 1884, a position held by him until his death.

His greatest contributions to botany are: the introduction of the laboratory method in teaching the science; his enrichment of the whole field of botany by teaching many new aspects of the subject; and his profound influence upon students and future investigators.

the slender parts inside the petals; (4) *pistil*, the central part of the flower; (5) *spur*, the projection on one of the sepals; (6) *peduncle*, the flower stalk.

How many sepals are there? Are they all the same size and shape? How many petals are there? Are they all the same size and shape? Have they all furrows, or streaks of color leading to the base of the flower? If not, which ones have one or the other? Which ones have a hairy fringe on the inside? Do the hairs all point in the same direction? Open the end of the spur and taste the liquid. Describe the taste.

How many stamens are there? Draw one and label (1) *filament*, the slender, stalk-like part; (2) *anther*, the enlarged top which contains yellow, dust-like particles, the *pollen*. If possible, examine pollen grains with a microscope. Describe them.

Draw the pistil. Label (1) *stigma*, the top portion; (2) *style*, the slender part below the stigma; (3) *ovary*, the enlarged base. Examine the stigma with a hand lens. Does it appear sticky? Can you see pollen grains on it? Cut across the ovary. How many chambers has it? How many *ovules* (small, white bodies) are in each chamber? Draw and label.

Examine a nasturtium blossom that has stood in water till it has withered. What parts of the flower have dried up? Which ones have fallen off? What parts remain? What changes have taken place in those that are left?

SUGGESTIONS FOR HOME WORK

Compare any blossoms you have at home with the nasturtium (geranium is a good one). Do you see any indications of irregularity in the geranium? of a spur? of colors or furrows on the petals? Examine other flowers in the same way — apple, violet, lilac, chickweed, etc. Make notes and sketches of what you find out for yourself, and of questions that occur to you.

In comparing the flower with the remarks about it in section 183, you will note that different parts of the flower have special names. Furthermore, you will find that many other flowers have all or some of the same parts. In order to talk about them intelligently, therefore, it will be necessary to know more about the parts of flowers, their names and their relations to one another.

184. Parts of a Flower Found in Nasturtium. — *Sepals* (Latin, *separ*, separate). — These are greenish pointed leaf-like parts on the outside of the flower. Together they make up the *calyx* (Greek, *kalyx*, cover), which protects the other parts, at least while they are in the bud, from insects, cold, rain, etc. One of the sepals has a spur in the bottom of which is a drop of nectar.

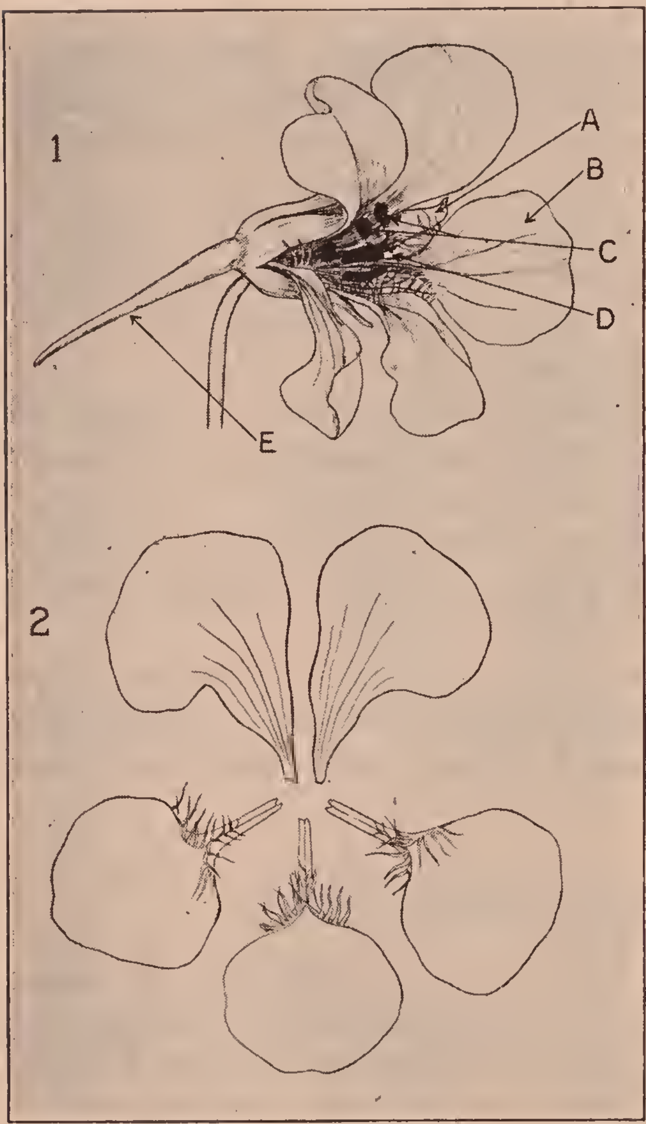

FIGURE 182. — FLOWER OF NASTURTIUM.
1, whole flower. *A*, sepal; *B*, petal; *C*, stamens; *D*, pistil; *E*, spur. 2, petals.

Petals (Greek, *petalon*, leaf). — The larger parts, more showy because more brightly colored, are *petals, which taken together make up the corolla* (Latin, *corolla*, crown).

Stamens (Latin, *sto*, stand). — These are the slender organs which surround the most central portion of the flower. The stamen has two parts, the *filament* or stalk, and the *anther* or box at the top, which contains the pollen.

Pistil. — The central portion of the nasturtium is the pistil, made up of three parts. At the top is (1) the stigma (Greek, *stigma*, point); below it (2) the style (Greek, *stylos*, pillar) which connects it with the lowest part, (3) the ovary (Latin, *ovum*, egg).

The sepals and the petals are sometimes spoken of as floral envelopes or as *accessory parts*, in distinction to the

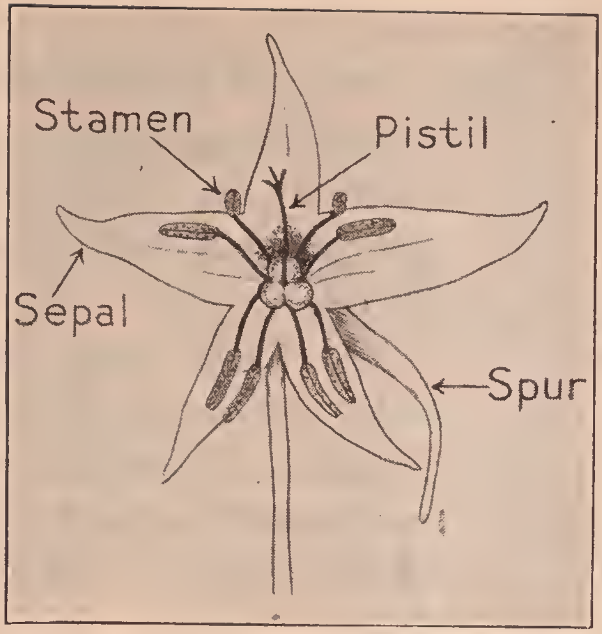

FIGURE 183. — FLOWER OF NASTURTIUM WITH PETALS REMOVED.

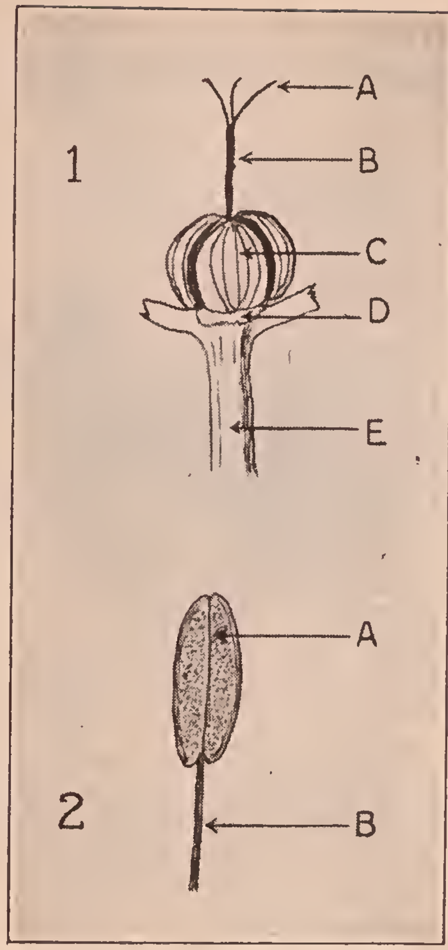

FIGURE 184. — PISTIL AND STAMEN OF NASTURTIUM.

1. *A*, 3-parted stigma; *B*, style; *C*, 3-parted ovary; *D*, receptacle; *E*, peduncle.
2. *A*, anther, with pollen; *B*, filament.

stamens and the pistil, the *essential parts*. Only the latter are necessary for the production of seeds. The nasturtium is a *perfect* flower because it has the parts necessary for the production of seeds, and it is a *complete* flower because it has also the accessory parts.

185. The Lily. — When the study of flowers is begun in the spring, the lily affords a good example. Let us see what adaptations it has. (1) It is a large showy flower. Insects can see it easily. (2) It has a strong odor, enabling insects to locate it by smell. (3) It has a long pistil which protrudes beyond the other parts, affording a good place for insects to alight. (4) It has long stamens so arranged that when an insect alights on the pistil, it is sure to become dusted with the pollen from them. (5) Its pistil has a sticky enlarged end which is almost sure to catch pollen grains from the insect's body. (6) It has nectar glands around the bases of the stamens which yield food for the insects. (7) It has

furrows in the petals leading to the nectar glands. This helps the insect to find the nectar. (8) The stamens bear the pollen on their outer surfaces, a safeguard against self-pollination. (See p. 211.)

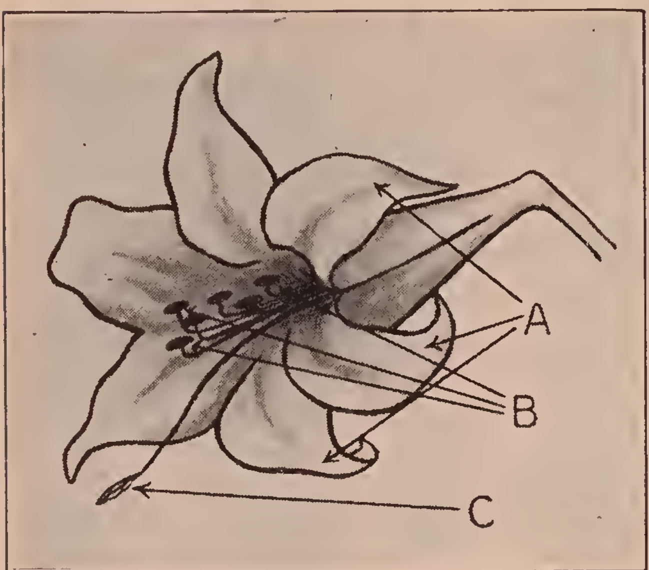

FIGURE 185. — FLOWER OF LILY.

A, divisions of perianth; *B*, stamens; *C*, pistil.

186. Parts of a Lily. — In speaking of the adaptations of a lily, several terms have been used which need to be explained further, as the parts which they represent are found in most flowers. The *pistil* is the central organ of the flower. It has three parts, (1) the expanded, sticky *stigma* (Greek, *stigma*, point) at the top, (2) the *style* (Greek, *stylos*, pillar), the long, slender connecting portion, and (3) the *ovary* (Latin, *ovum*, egg), the expanded base. Inside the ovary are the *ovules* which contain the egg cells from each of which an embryo plant will develop if it becomes fertilized. The part of the ovary to which the ovules are attached and through which they get their food is the *placenta*. The *stamens* (Latin, *sto*, stand) are the parts of the flower outside of the pistil and surrounding it. Each stamen consists of a slender stalk, the *filament*, and an *anther*, the part which contains the pollen. The stamens and the pistil make up the *essential* parts of the flower, for with them alone, seeds can be produced. Around the outside

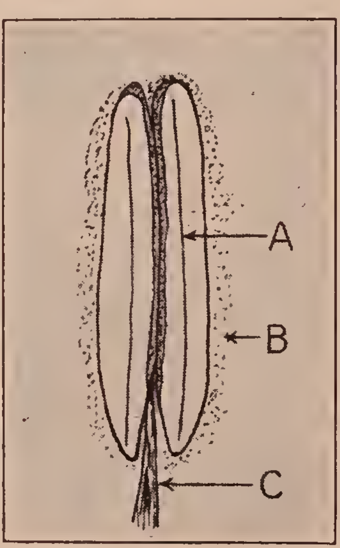

FIGURE 186. — STAMEN OF LILY.

A, anther; *B*, pollen grains; *C*, filament.

of these organs are the colored parts which together form the perianth of the flower (Greek, *peri*, around, *anthos*, a flower). In the lily the perianth consists of six parts of the same color, size, and shape. Because of the even size and regular shape of the parts of the perianth of the lily, we speak of it as a *regular* flower. The perianth is an *accessory* part of the flower, for seeds can be made without it, the stamens and the pistil being the only *essential* parts. Any flower which has all the parts which a flower may have is called a *complete* flower. If it has both stamens and pistil, the essential parts, it is called a *perfect* flower.

LABORATORY STUDY OF A LILY

Each pupil is to be provided with a lily.

Draw the flower and label the parts as follows: (1) *perianth*, the large outer parts taken together; (2) *stamens*, the slender parts bearing the yellow, dust-like *pollen;* (3) *pistil*, the central part of the flower; (4) *peduncle*, the flower stalk.

How many divisions has the perianth? Are they all the same shape, size, and color? Have they all furrows or markings leading to the base of the flower? Are there drops of *nectar*, a sweet substance at the base of the stamens?

How many stamens are there? Draw one and label (1) *filament*, the stalk-like part; (2) *anther*, the enlarged top which bears the pollen; if possible, examine the pollen grains with a microscope.

Draw the pistil and label (1) *stigma*, the enlarged upper end; (2) *style*, the slender portion below the stigma; (3) *ovary*, the enlarged base. How many lobes has the stigma? Is it sticky? Are there pollen grains upon it?

Cut across the ovary. How many chambers has it? Are there few or many ovules (small, white bodies) in each? Draw. Label the parts to which the ovules are attached, *placenta*.

Let a lily stand in water till it withers. What parts have dried up? What other changes have taken place? Cut across the ovary. Compare with your drawing and tell what differences you see. Draw the ovary as it now appears.

Besides the four sets of parts found in nasturtium flowers, other parts will be found in certain flowers, the *receptacle*,

for example, the expanded top of the stalk on which the floral organs are placed. This is sometimes oval as in buttercups, or large and fleshy as in strawberries, or hollow as in the rose, where the pistils arise from its inner surface. The *crown* is a projection growing from the surface of a petal as in narcissus. The *spur* already mentioned is another modification of a petal or a sepal. Violets, snapdragons, toad flax, and larkspur have spurs. Nectar glands, usually found near the base of a flower, are commonly found in those flowers which are adapted to attract insects.

187. What Is a Flower? — It has been decided that a flower is simply a modified branch, the parts of the flower being highly specialized or modified leaves. Some flowers show this plainly at all times, and others show it under certain conditions.

188. Uses of the Parts of a Flower. — The sepals are adaptations for the protection of the inner organs while they are developing, and the petals are adaptations for the purpose of attracting insects to distribute pollen. Sometimes one set of these organs is lacking and sometimes the other, giving us *asepalous* or *apetalous* flowers as the case may be. Very often, sepals are colored and serve the purpose of petals, another adaptation. The receptacle serves as the place of attachment for the other parts of the flower.

Stamens. — These produce the pollen without which seed cannot be formed. Concerning the ways in which they open, the kind of pollen they bear, their adaptations for getting it to the pistil of another flower and (usually) for keeping it from its own, enough has been discovered to furnish text for a whole book, although many flowers have not yet been studied at all. Many of these facts can be observed by any boy or girl with keen eyes. To be on the lookout for new facts will give zest to the study of botany.

Pistil. — In the ovary of the pistil are found the ovules which will become seeds under favorable conditions (see

sections on Pollination and Fertilization). The stigma and the style are parts which help to fulfill these conditions. The position of the ovules in the ovary, the adaptations of the stigma for catching and holding pollen, the position of the stamens with reference to it, the adaptations of the pistil for the passage of the pollen tubes through it, — all these furnish the basis for a fascinating study which can be carried on by anyone who has access to flowers, and who has time and patience.

FIGURE 187. — STAMINATE FLOWERS OF CORN, THE "TASSEL."

When a flower has finished its work, namely to secure the fertilization of its ovules, its showy parts wither, if it had any, and the fruit begins to form. Usually it is only the ovary which enters into the fruit; but in some cases, the receptacle is included, and in others the calyx remains unchanged.

The biologist who is interested chiefly in adaptations of flowers and in their relations to insects will not need many scientific terms for his work. Persons who have occasion to classify plants, however, need to know a few more terms. Farmers and gardeners need to know other facts about flowers. For them still other terms are necessary.

189. Other Terms Used in Describing Flowers. — Flowers which lack any one of the four sets of parts which the nasturtium has are *incomplete* flowers. The apetalous flowers of the grasses are examples.

Imperfect flowers bear only one of the essential parts of a flower; so we find *staminate flowers*, bearing stamens only,

like the tassel of the corn, and *pistillate flowers,* bearing pistils only, like the young ear of corn with its long silks (pistils). Some plants, like the corn, bear both kinds on the same plant, even though in separate flowers. In this case we say the plant is *monœcious* (mo-nē′shŭs: Greek, *monos,* one; *oikos,* house). Other plants have only staminate or only pistillate flowers like the willow and ash which we call *diœcious* (dī-ē′shŭs: Greek *di,* two; *oikos,* house) plants.

FIGURE 188. — PISTILLATE FLOWERS OF CORN.

Immature grains, each of which has a long, green style, the "silk." The husks are modified leaves.

Regular flowers are those which have all the parts of a kind the same size and shape. Such a flower is the lily.

Irregular flowers have many variations, but they are all alike in having the parts of the same set of different size and shape. The bean flower, the nasturtium (see Figure 182), and the violet illustrate this.

Double flowers are those in which the stamens or part of them have turned to petals. How would this affect the production of seed? *Cleistogamous flowers* (klīs-tŏg′a-mŭs: Greek, *kleistos,* closed; *gamos,* marriage) are those which some plants form for the sole purpose of producing seeds without the help of insects. They usually grow below the surface of the ground, have no petals, have only one or two

stamens, and they never open. The sepals protect them, the parts are so arranged that none of the pollen is wasted, and the number of seeds produced is even larger than in an ordinary flower. Violets make use of this kind of flower after the others have finished blooming.

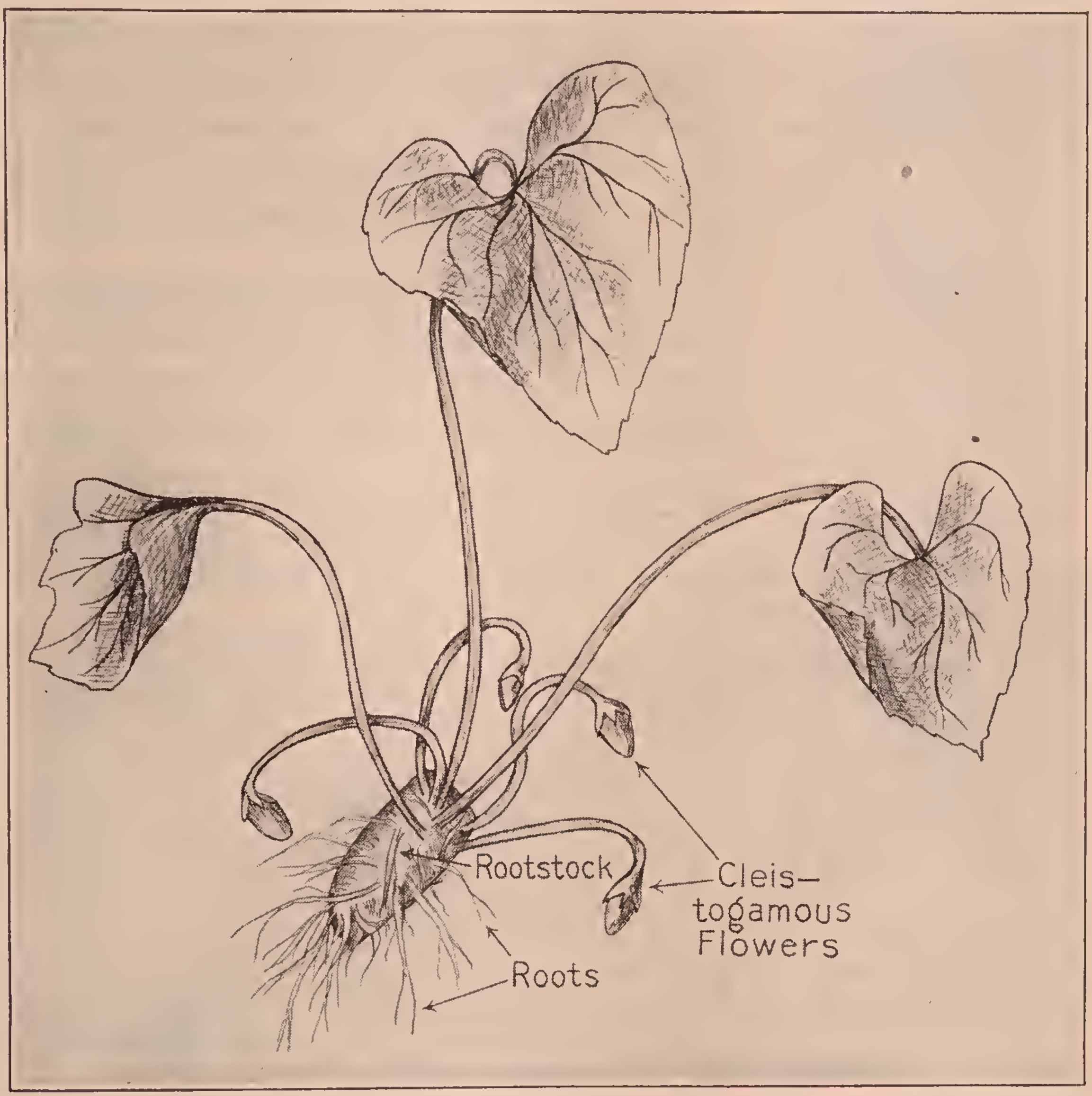

FIGURE 189. — VIOLET. PLANT WITH CLEISTOGAMOUS FLOWERS.

SUGGESTIONS FOR DEMONSTRATION BY TEACHER

Direct the observations of pupils in studying the flowers of a dandelion. Note old (mature) flowers on the outer part of the head, and young (immature) flowers in the inner part. Note the notches at the end of the long corolla. What does this indicate? Note the number of filaments, and the anthers united in a ring, opening on the inside. Call attention to the fact that the anthers mature before the pistil does.

Show how the pistil, with its stigmatic surfaces pressed tightly together, pushes up through the pollen which fills the tube, becoming covered on the outside. Show mature pistil with expanded stigma. If possible show dandelions with insects on them. What are the insects doing? What happens to the pollen?

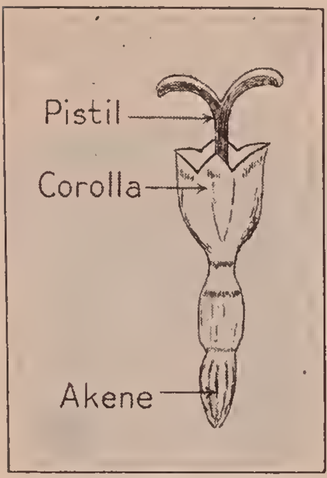

FIGURE 190. — DISK FLOWER OF DAISY.

Pollen grains. — Place a few, preferably large ones, on a slide; cover with 5 per cent sugar solution; put under a bell jar and set in a warm place for half an hour. Then add a cover glass and examine for pollen tubes. Examinations may be repeated at intervals for a number of hours.

Carefully split the style of a large flower, like a lily, noting the passage in the middle for the pollen tubes. If the pistil has not a tubular center, what is the character of the tissue in the center?

190. Composite Flowers. — These flowers are closely crowded or grouped into a head, on a common receptacle. Such is the dandelion or the daisy, each group being commonly called a flower. Two kinds of flowers are to be found in these heads, *tubular flowers*, that is, with the corolla a tube, and *strap-shaped* flowers in which the corolla is long and slender. Some composite flowers, like the dandelion, have only the strap-shaped, and others, like the thistle, only the tubular kind. Still others, like the common daisy and the sunflower, have both kinds. In the daisy, the tubular flowers, found only in the middle, are called *disk flowers*. These make up the yellow part of the group. Outside of them are the white strap-shaped kind, known as the *ray flowers*. In the sunflower the disk flowers are brown, and the ray flowers yellow. Many other combinations occur.

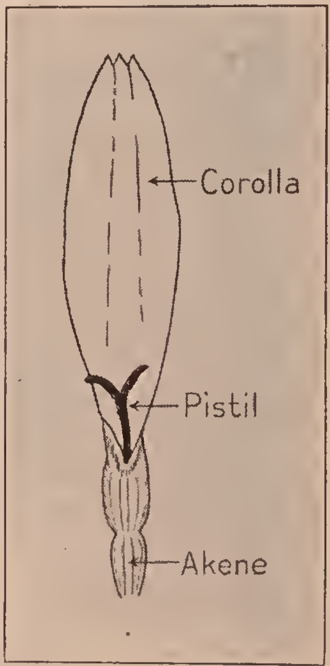

FIGURE 191. — RAY FLOWER OF DAISY.

Dandelion flowers show many adaptations. The stamens are joined in a ring with the anthers opening on the inside of the ring. The anthers mature their pollen before the pistil of that flower is ready for pollen. The pistil, with its stigmatic surfaces pressed tightly together, pushes up through the mass of pollen filling the tube, becoming covered on the *outside*. Insects crawling over the head drag some of these pollen grains to pistils which are mature. When the pistil of any one flower expands, its own pollen is not likely to get on it.

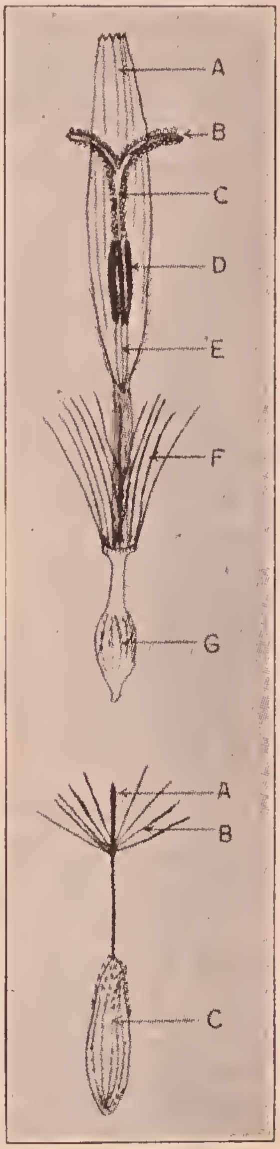

FIGURE 192. — FLOWER AND FRUIT OF DANDELION.

Upper figure, *A*, strap-shaped corolla; *B*, stigma; *C*, style, covered with pollen grains; *D*, stamens united by their anthers; *E*, filaments; *F*, pappus; *G*, akene.

Lower figure, *A*, remains of flower; *B*, pappus; *C*, akene.

The closely crowded flowers, the arrangement of their parts, the bright color, the abundant pollen and the certainty of cross-pollination are adaptations which make the dandelion one of the most successful of plants.

The composites as a whole show more adaptations than other flowers, so we find among them those which are of most interest to the scientist and those which are of greatest annoyance to the farmer, namely, wild carrot, paint-brush, burdock, and thistles of all kinds. They are most successfully fought by not giving them opportunity to blossom and form fruit. In some cases, roots as well as seeds serve to propagate plants. Taproots (page 250), characteristic of some plants, help them to maintain themselves under unfavorable conditions, and rhizomes (page 334) help the plants which have them to spread.

HOME WORK

Examine vacant lots, waste spots, and gardens for weeds. How many of them are composites?

Study flowers in vacant lots, and record the results, using the following table as a guide.

	Corolla Regular	Corolla Irregular	Corolla Lacking	Stamens only in a Flower	Pistils only in a Flower	Flower Perfect
Geranium . . .	X					
Castor bean . . .						
Salvia		X				
Nasturtium . . .						X
Pansy		X				
Etc.						

191. Pollination. — When insects go to a plant they generally have a definite errand, namely, to get pollen or nectar from it. As shown by the nasturtium, or the lily, they are helped in this by adaptations of the flower. At the same time, the flower has other adaptations which cause the insect to become covered with pollen as it leaves the flower, and still other adaptations which bring it about that when the insect enters a flower, some of the pollen from the flower last visited is left on the stigma of the one which it is entering.

Pollination is only the first step in the production of seed. Before we can understand the use of pollination, we must understand the structure of the pollen grain.

Pollen grains present the greatest variety in size, structure, and markings, but all have some features in common. They all have a double coat or covering, the outer of which is thin in places. When a pollen grain is caught on a sticky stigma, it soon sprouts; that is, the inner coat pushes out through the thin places in the outer coat, producing a tube.

This contains the protoplasm of the pollen grain, and two nuclei, one of which, the *sperm nucleus*, will join with that found in the ovule, the *egg nucleus*, to start the new plant formed in the seed.

The pollen tube and the style both show adaptations. The style is either tubular, affording a path for the pollen tube,

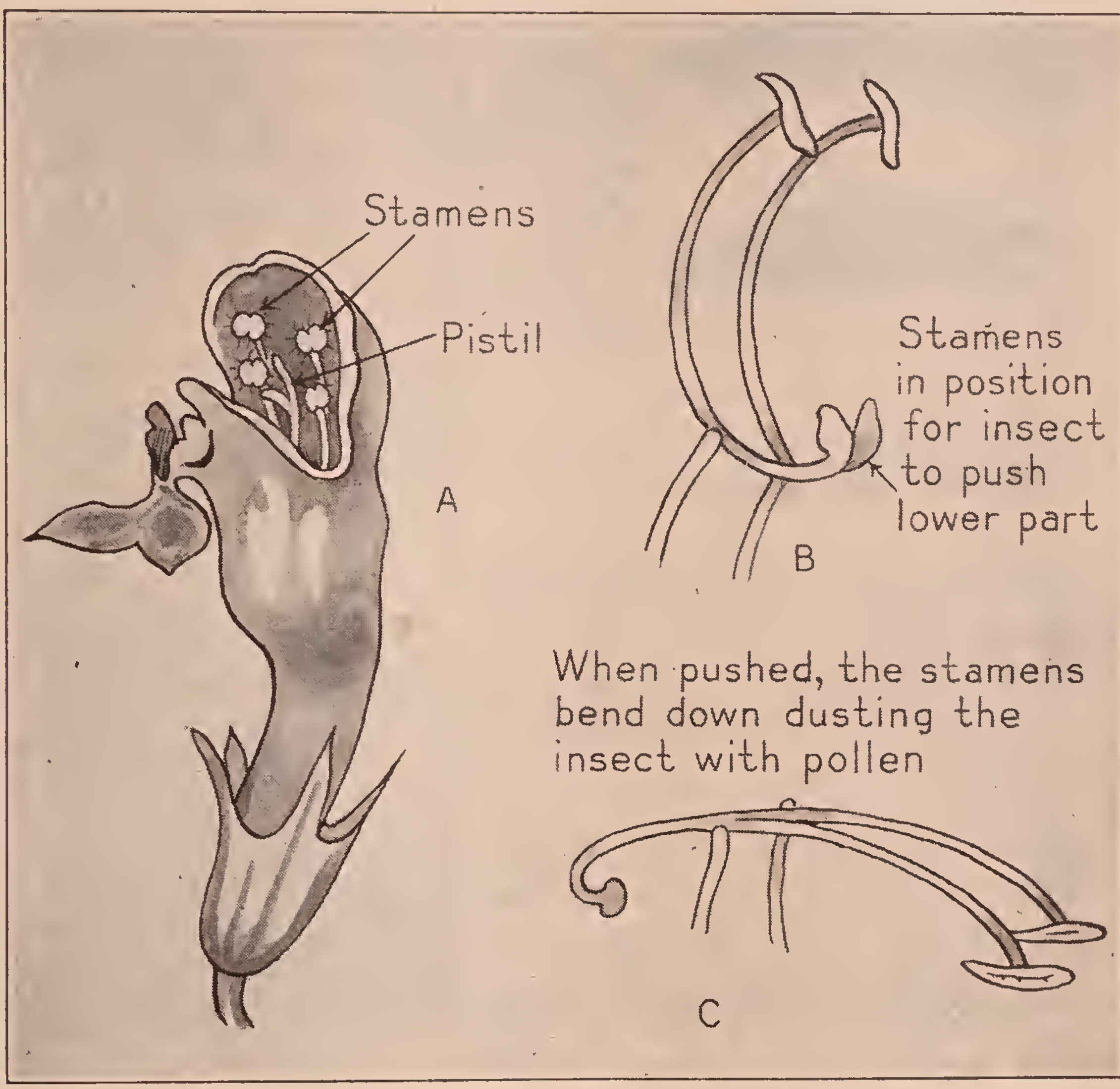

FIGURE 193. — FLOWER OF SALVIA.

A, whole flower. Note the platform where the insect alights.

or it is composed of cells very loosely packed, allowing the tube to pass through it readily. The adaptations of the tube are its ability to absorb food from the tissues through which it passes, and to find the micropylar opening of the ovule.

Cross-Pollination. — Reference has been made to the fact that pollen is necessary for the formation of seeds, and that in most cases it is the pollen of some other plant of the same kind that is used. When the pollen of one flower is transferred to the stigma of another of the same kind, the process is known as *cross-pollination.* On the other hand, when a stigma gets pollen from the stamens of its own flowers it is said to be *self-pollinated.* The distribution of pollen is accomplished by insects and by wind more than by other agents. Pollen that is to be scattered by wind has two adaptations: (1) it is very abundant, for much of it is sure to be lost; (2) it is light, that it may be easily carried. The pollen of pines which is so abundant as to cause the so-called "sulphur showers" in the spring illustrates this, and the pollen of grasses which is extremely light illustrates the other fact. Plants that are wind-pollinated usually lack odor and color and floral envelopes (accessory parts), but they have adaptations in the stigmas, which are either plumy or feathery or broad and sticky, the better to catch and hold the pollen grains brought to them by the wind.

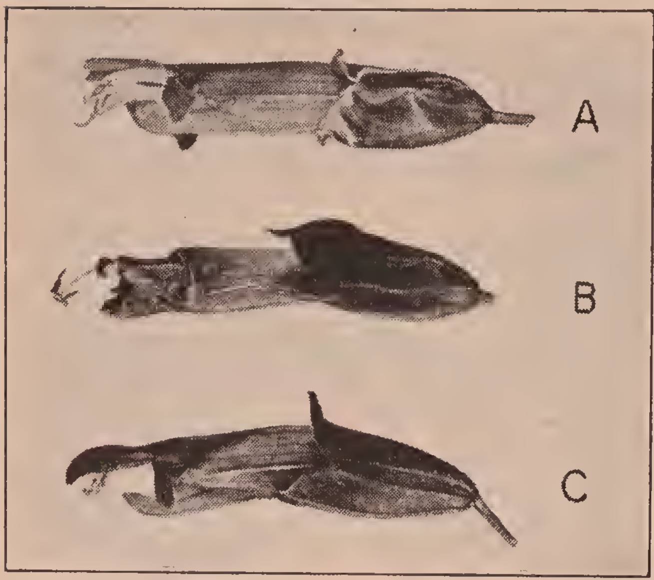

FIGURE 194. — SALVIA.
A, stamens mature; *B*, pistil mature; *C*, flower after pollination.

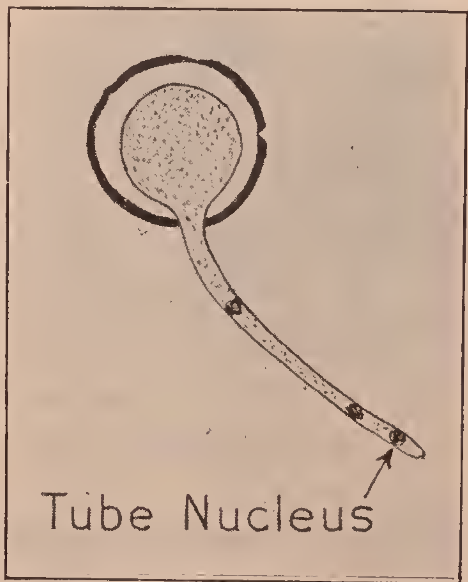

FIGURE 195. — POLLEN GRAIN SPROUTED.
The upper nuclei are male or generative nuclei.

Seeds formed as a result of cross-pollination produce more vigorous plants than those which grow from seeds in self-pollinated flowers.

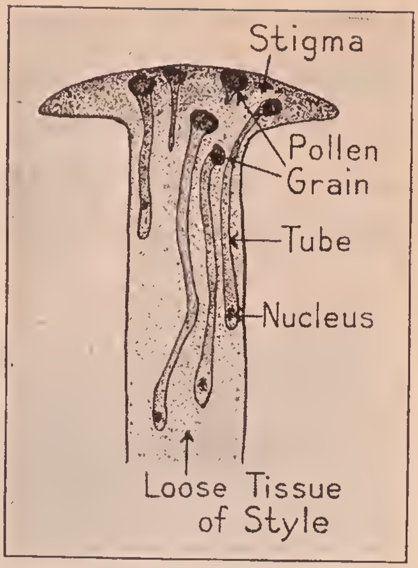

FIGURE 196. — POLLEN GRAINS SPROUTING AND GROWING THROUGH STYLE.

Self-Pollination. — Some flowers, like the cleistogamous flowers of the violet, are arranged with a view to securing self-pollination. Most flowers, on the other hand, have adaptations to prevent it. One of these is bearing unisexual flowers only, pistillate and staminate flowers, on different plants as the willow does. Another is having pistil and stamens mature at different times (dandelion, see p. 207); and a third is having stamens and pistils of different lengths. When an insect visits such a flower, one part of its body is apt to come into contact with the stamens and another with the pistil. For example in the primrose, an insect which gets pollen from short stamens on its body in one flower leaves it on the short stigma of another flower.

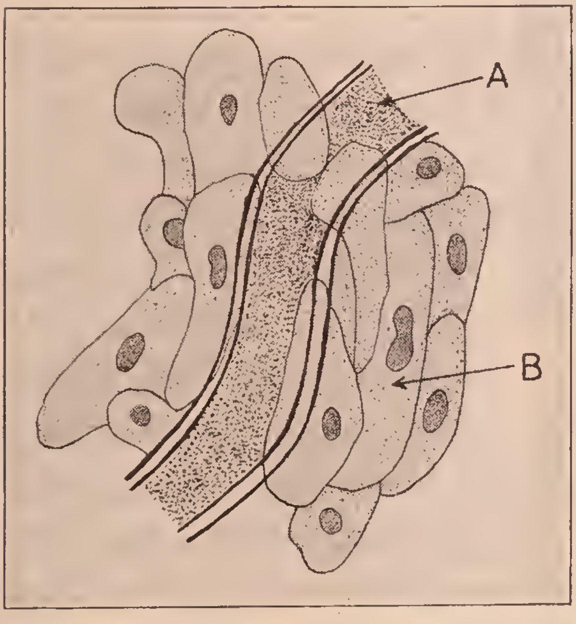

FIGURE 197. — POLLEN TUBE, ENLARGED.
A, tube; *B*, loose cells of style.

192. Fertilization. — The union of the pollen nucleus with the nucleus of the egg cell is called fertilization. Without it, the ovule never develops into a seed. (Look in pea or bean pods for unfertilized ovules; in the seed-case of an apple; on an ear of corn.)

Successful fertilization depends much on thorough pollina-

tion. For this reason farmers and gardeners should know the habits of the insects which pollinate flowers and the best way to plant certain crops to secure the results desired.

193. How Fertilization Is Accomplished. — When pollen grains fall on a stigma they are held there by a sticky substance or by projections, and each soon puts forth a tube as already explained. The tube makes its way through the style either by means of a channel which traverses it or by making a path for itself through the loose tissue of which styles without channels are composed. The nuclei are always near the end of the tube, which may become very long compared to the size of the grain which produced it. (See Figure 195.) When it reaches the ovary it turns towards an ovule which it enters usually through the micropylar opening. When the tip of the tube containing the male nucleus touches the egg cell in the embryo sac, it bursts, and its nucleus unites with that of the egg cell, completing the act of fertilization. The ovule at the time of fertilization consists of a mass of tissue known as *nucellus* (Latin, *nucella*, small nut), which is enclosed by an outer and an inner *integument* (Latin, *in*, upon, *tego*, cover) except at one point, the micropylar open-

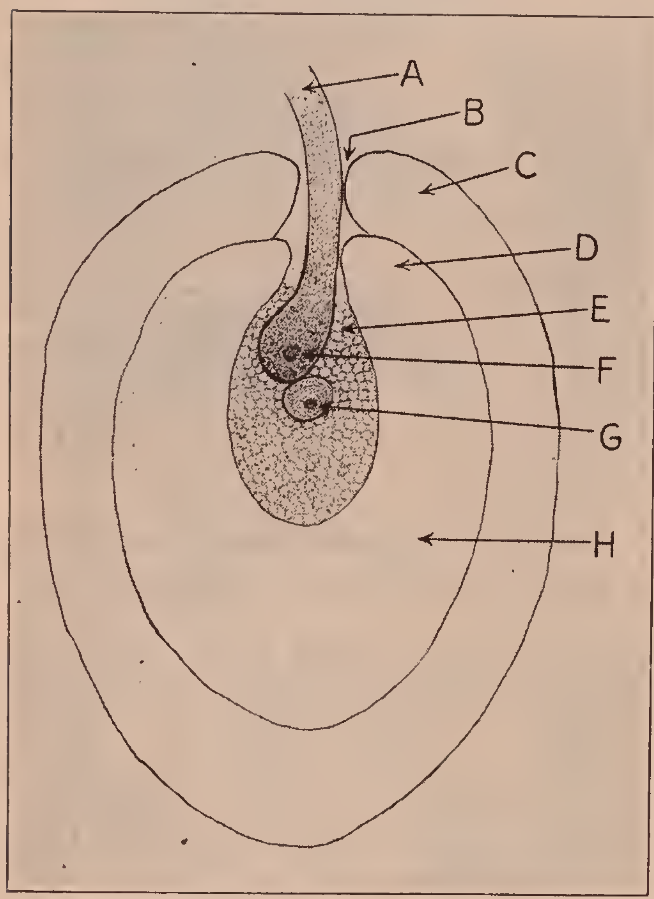

FIGURE 198. — POLLEN TUBE ENTERING OVULE IN ACT OF FERTILIZATION.

A, pollen tube; *B*, micropyle; *C*, outer integument; *D*, inner integument; *E*, embryo sac; *F*, male nucleus; *G*, female nucleus; *H*, nucellus.

ing. Imbedded in the nucellus is the *embryo sac* containing the egg cell which, if fertilized, will develop into a new plant. The ovule is attached to the ovary by a stalk called the *funicle* (Latin, *funiculus*, little rope) through which it receives food for its growth and development.

As soon as the egg cell is fertilized it begins to divide, forming the new plant. At the same time other changes take place which result in the formation of a seed. (See page 219.)

In the early days of the study of botany, persons were interested more in describing flowers minutely and in classifying them than in learning about how they lived. Although the latter is now of greater interest, we still need many of the terms formerly used to describe the plants in order to read about them intelligently. For this reason, the ones most commonly used are given in the text or in references.

FIGURE 199. — UMBEL.

A flower cluster in which the pedicels arise from a central point. If the pedicels have the same length, the cluster is globular, as in the milkweed. If the outer ones are longer, the cluster is flat, as in the wild parsnip.

194. Inflorescence. — Flowers that grow at the end of a separate stalk, like the common blue violet, tulip, daffodil, waterlily, and hepatica, are *solitary flowers*. This term is used also for the single flowers which spring one from the axil of each leaf as in pimpernel. As a rule, solitary flowers

are larger and more showy than those which are arranged in clusters.

The more common flower clusters can be identified by reference to the illustrations and to the explanations accompanying them. Note that the flowers in a cluster are, in general, smaller or less conspicuous in color than are the solitary ones.

FIGURE 200. — COMPOUND UMBEL OF WILD CARROT.

Note the fly which in crawling around is distributing pollen.

Raceme. — This is a stem which bears flowers on both sides or spirally, each flower having a bract or reduced leaf at its base. The flowers may all hang from one side of the stem as in lily-of-the-valley or currant.

Compound Raceme. — Here each pedicel branches regularly, as false Solomon's seal.

Thyrse. — This is a compact panicle forming an oval or pyramidal cluster, as bunch of grapes, lilac, horse-chestnut blossoms.

Head. — This is a raceme in which the axis is very much flattened, or much rounded, as clover.

Corymb. — This is an inflorescence in which the lower pedicels are longer, forming a flat-topped cluster, as hawthorn. How does this cluster differ from the umbel of the wild parsnip in appearance and in structure?

In forget-me-not, hound's tongue, and heliotrope, only

FIGURE 201. — COMPOUND UMBEL OF WILD PARSNIP.

Note the maturing fruit.

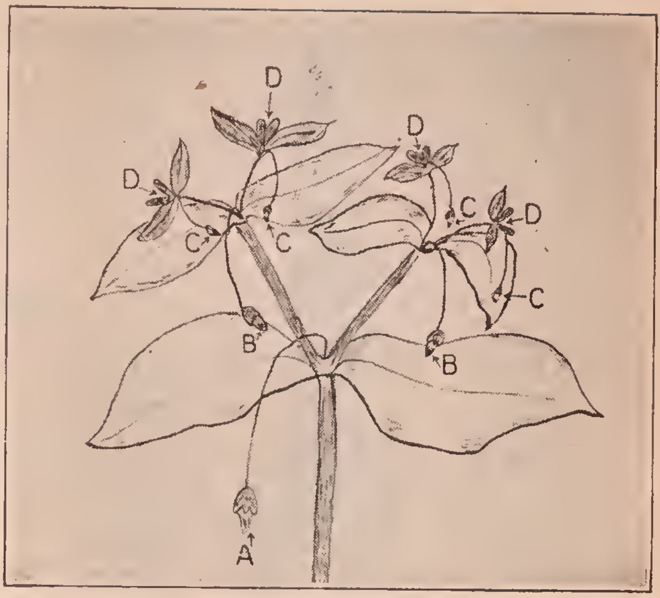

FIGURE 202. — CYME OF CHICKWEED.

A cyme is a flower cluster in which the terminal flower opens first (*A*). Next in order, the terminal flower on each of the two axillary branches arising below it (*B*). Third in order, four flowers, one on each apex of the two branches arising from the axis of each flower of the second series (*C*). What does *D* represent? How many will there be?

FIGURE 203. — PANICLE.

A raceme in which the branching is somewhat irregular, and the branchlets long, as head of oats or panicle of grass.

FIGURE 204. — COMPOUND CYME OF ELDER.

FIGURE 205. — SPIKE.

A raceme in which the flowers have very short pedicels or none, as plantain, Figure 206.

one axillary branch arises below the terminal flower each time, all on the same side.

In a raceme, spike, panicle, and head, the axis may go on growing and producing flowers during an indefinite period.

In solitary flowers only one is ever produced on a peduncle ; and in a cyme only the terminal flôwer is ever produced on any one branch.

The first group is known as *indeterminate inflorescence* and the second as *determinate.*

Indeterminate inflorescence has its oldest flowers on the lower part of the axis (raceme, spike, head) or on the *outside* of the cluster (corymb, umbel). The order of blossoming is centripetal.

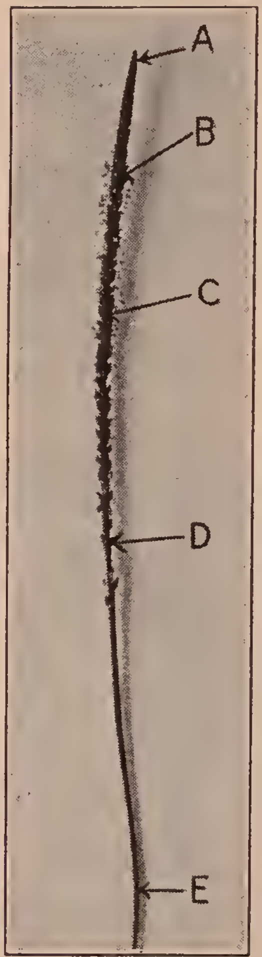

FIGURE 206.

A, region of mature pistils; *B*, region of mature stamens; *C*, region of maturing fruit; *D*, region of ripe fruit.

In the cyme the *central flower* is the oldest, producing others farther away with each branching, the order being centrifugal.

195. Economic Value of Flowers. — Many plants are cultivated for the pleasure their flowers give us. Our use of them for pleasure very often defeats the object for which they

grow, from Nature's standpoint, for they do not have a chance to develop seeds.

Cauliflower and Brussels sprouts, the buds of which are used as food, are the most familiar examples of the use of flowers for this purpose.

A few have been used for medicine, though not so much now as formerly. Among them may be mentioned dandelion, the elder, the mullein, and camomile.

Saffron, a yellow coloring matter, is obtained from the stigmas of the saffron crocus.

SUGGESTIONS FOR HOME WORK

As soon as flowers appear observe them closely and note which have many insect visitors and which have few or none. Fill out a report as suggested below and add any points which interest you besides those mentioned.

	Color Conspicuous	Color Not Conspicuous	Odor Strong	Odor Not Strong	Nectar Abundant	Nectar Not Abundant	Insects Many	Insects Few	Etc.
Sweet Pea .									
Dandelion .									
Hepatica .									
Buttercup .									

Examine florists' and gardeners' catalogues, and note the plants the flowers of which are used as food and for ornament. Read about the use of hops and the process of raising and harvesting them.

SUMMARY

The flower is the part of the plant that produces fruit containing seeds for a new generation of plants. The essential parts of a flower are the stamens and the pistil,

which may not be in the same flower or even on the same plant. Other parts are merely accessory, being found in those flowers which depend on insects for cross-pollination. Large, showy flowers are not grouped; but small, inconspicuous ones are, to attract insects. Pollen which is distributed by wind is very light and very abundant. Stigmas which depend on wind for pollination are plumy or sticky or both. Fertilization of the egg cell in the ovule is accomplished when the sperm nucleus in the pollen grain unites with that of the egg cell. A flower may be defined as a device to secure pollination.

QUESTIONS

Into what two groups may the organs of a plant be divided? What organs are in the first group? What in the second? Name all the parts that a flower may have. Tell the use of each part. What are some of the adaptations of flowers that attract insects to them? What peculiarities have flowers that are pollinated by the wind? What is fertilization?

REFERENCES

Bessey, College Botany, page 285; pages 302–313; 321–324.
Snyder, General Science, pages 200, 201.
Bergen, Foundations of Botany, 186–216.
Conn, Biology, page 118.
Bergen and Caldwell, Practical Botany, pages 104–135.
Gibson, Sharp Eyes, page 115.
Coulter, Plant Life and Plant Uses, page 58; pages 258–321.

CHAPTER XVI

THE SEED AND THE SEEDLING

196. From Ovule to Seed. — At the time of fertilization, an ovule consists of a mass of tissue (*nucellus*) in which is embedded the *embryo sac*. The embryo sac contains an egg cell which, if fertilized by a nucleus from the pollen tube, will become a young bean plant (embryo). The ovule is covered by two coats (*integuments*) which do not quite meet at one end, leaving an opening, the *micropyle* (mī′krō-pīl: Greek, *micro*, small; *pyle*, gate), a small door through which the pollen tube usually enters. It is attached to the wall of the ovary (placenta, see § 184) by a stalk (funicle, see § 193) through which it gets its nourishment.

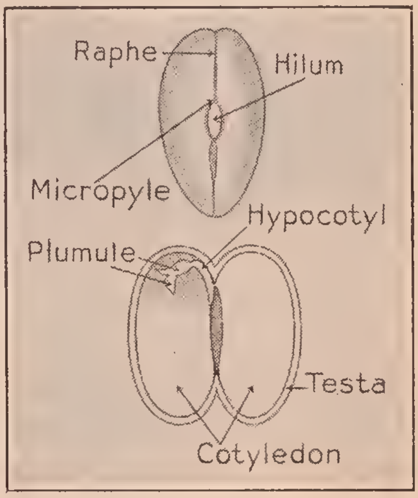

FIGURE 207. — BEAN SEED SHOWING PARTS.

In developing into a seed several changes occur. (1) The integuments become firm and hard, the outer forming the *testa*. (2) The egg cell divides, forming the *embryo*. (3) The embryo sac is replaced by two *cotyledons* (kŏt-y-lē′dŏn: Greek, *kotyledon*, socket) which contain food for the embryo. (4) The micropyle becomes smaller and almost closes. (5) The funicle drops off, leaving a scar on the bean seed, the *hilum* (hī′lŭm: Latin, *hīlum*, a little body).

197. Adaptations of the Seed. — The bean seed is the plant's way of providing for a new bean plant. It is adapted to fulfill that purpose in the following ways. (1) A ripe seed

contains a young plant well started. (2) It can resume growth soon after being formed, or it can remain dormant for years. This might prevent total loss of seed. (3) It is surrounded by a hard testa which prevents the embryo from drying out during a long resting period. This enables it to remain *viable* (Latin, *vita*, life) for many years. (4) It can absorb water slowly through the micropyle when covered with moist earth. This softens the testa and causes the cotyledons to swell, helping to release the embryo. (5) The cotyledons contain food for the young plant till it can make its own. This insures rapid growth in the early stages, an advantage in competition with other seedlings.

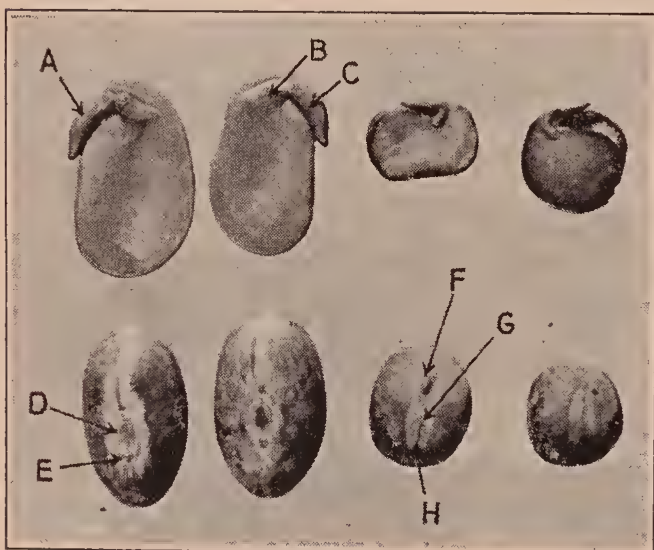

FIGURE 208. — SEEDS OF BEAN AND PEA.

Upper, split, showing embryo. (Only the part showing the embryo was saved.) Lower, whole, showing markings. *A*, embryo; *B*, plumule; *C*, root; *D*, hilum; *E*, micropyle; *F*, embryo; *G*, hilum; *H*, micropyle.

198. Growth of the Bean Embryo. — When the embryo resumes growth after a resting period, the root breaks out of the testa first. This is an adaptation, for it at once begins to absorb water needed for further growth and soon becomes firmly imbedded in the soil. The second adaptation is the curving of the hypocotyl (hy-pō-kŏt″l: Greek, *hypo*, beneath; *kotyle*, cavity). This forms a loop on top of which is a hard portion, the *peg*. The hypocotyl grows rapidly, causing the arch of the loop to turn from side to side, pushing the particles of soil apart and working its way to the surface. Then the cotyledons are pulled up as the arch straightens. Finally, further growth of the hypocotyl

causes the cotyledons to spread apart, exposing the *plumule* (plūm′ūl: Latin, *plumula*, feather) to the air and light. At the same time the cotyledons begin to turn green, thus serving as leaves till the leaves of the plumule have developed. So the plumule is protected and given a chance to grow under good conditions. As soon as the food in the cotyledons is absorbed by the young plant, they shrivel and drop off.

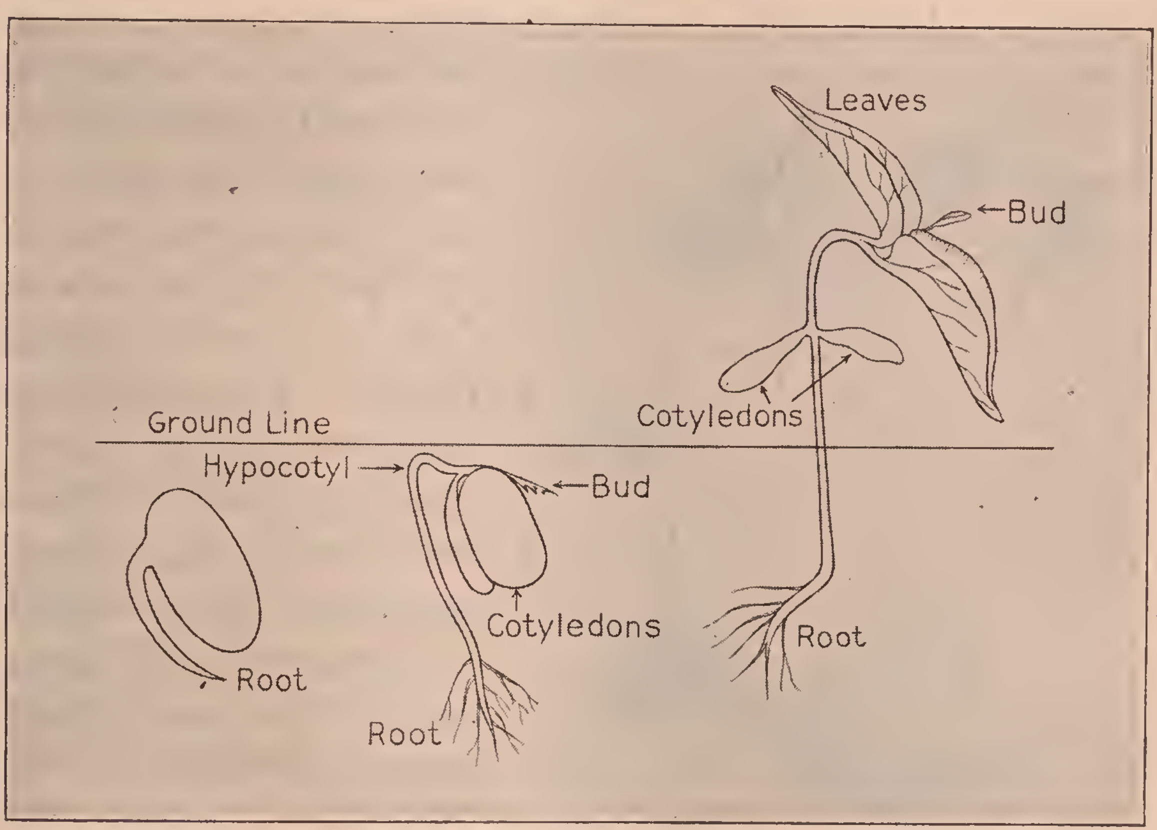

FIGURE 209. — GERMINATION OF BEAN.

Left, root free; center, root branched, hypocotyl developed and showing the arch, cotyledons split apart, and plumule; right, young bean plant showing shriveled cotyledons, and first true leaves.

The young bean plant is known as a seedling, while it is dependent on the store of food in the seed.

In the course of a few weeks a bean plant is large enough to produce blossoms which develop into pods containing seeds, thus completing the life *cycle*. The use of the seeds to the plant is simply to provide for other plants of the same kind, and to insure a supply of food for the early life of each. Man, however, has learned to take advantage of this habit

of plants, to secure food for himself and his animals. He has also found ways of enabling the plant under cultivation to store up more food than it could do in the natural state.

199. Economic Uses of Seeds. — In thinking of the seeds used as food, we must limit the term to its botanical meaning. Many articles of food, such as the cereal grains, are commonly thought of as seeds. Their use as food has already been discussed. (See § 197.) The real seeds that are of greatest use to man as food are those of the pulse family, especially beans and peas, which alone are the source of most of the protein that is obtained from plants. The meats of nuts are another source of protein food. Mature peas and beans contain more food matter than do "green peas" and "string beans," the latter being valuable more for the bulk they furnish than for their food content.

FIGURE 210. — BEAN SEEDLINGS.
All the food these plants have used came from the cotyledons, as the jar contained only sawdust.

Besides their use as food, seeds can be used as medicine, castor oil and mustard being common remedies that are obtained from seeds. Castor oil is also used as a lubricant in airplanes on account of its not being affected by the cold of high altitudes. Two valuable products are obtained from cotton seeds: one the oil which is used in preparing foods in place of lard and butter, animal fats; the other, thread and cloth which are made from the fibers covering the outside of the seeds. The fibers are removed by a process

called ginning; then the seeds are pressed to remove the oil. The refuse forms a valuable food for cattle, especially when mixed with other foods. The length of the fibers varies on different species of cotton, and the uses which are made of the fibers depend on their length.

Linseed oil is obtained from the seeds of the flax. It is used in making paint and other substances.

200. Dormancy. — Most seeds have a rest period, or *period of dormancy* as it is called. This is longer in wild plants than in cultivated ones. In most seeds the dormant period is only from the summer of one year to the spring of the next. In pigweed, however, the seeds of any one year may require several years for development, owing to differences in the thickness of the testa. Those grow first which have the thinnest testa. Years may pass, therefore, before all the seeds of a single crop have grown. This fact and the great number of seeds produced are the two main reasons why this weed is so persistent. Once it has seeded, it has the ground supplied with seeds that will grow some one year hence, some two, and so on up to thirty years. Other weeds which produce seeds that can lie dormant for at least thirty years are shepherd's purse, black mustard, chickweed, and curly dock. Variations in the thickness of the testa in seeds on the same plant is an adaptation which prevents the plant from drying out even if unfavorable conditions cause the death of all the seedlings of any one year. Closely related to the dormancy of a seed is its *viability*, or power to grow after long periods of rest. It has been proved by experiments that the seeds of weeds mentioned above are viable or able to grow after a dormancy of thirty years. Such facts as have been established by experiment lead us to discredit stories about the growing of seeds that have lain in Egyptian tombs hundreds of years.

Practical use can be made of this knowledge by any one who cultivates crops. For instance, weeds that depend on

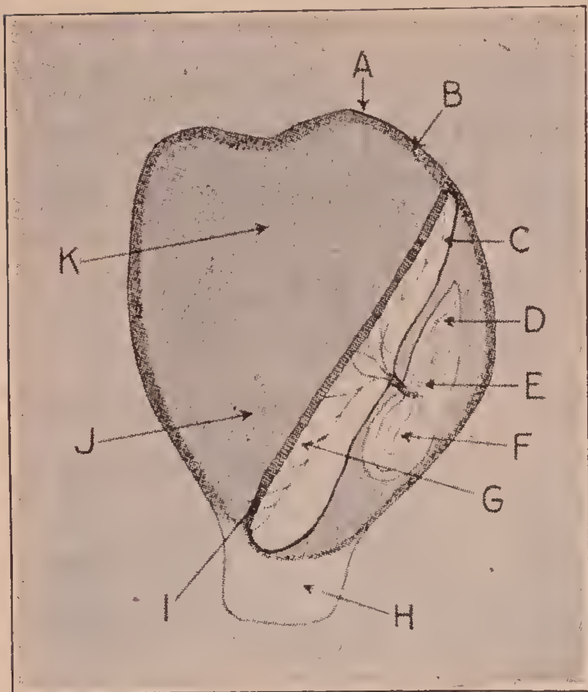

FIGURE 211. — DIAGRAM OF GRAIN OF CORN.

A, hard outer covering; *B*, protein; *C*, scutellum; *D*, plumule of embryo; *E*, hypocotyl; *F*, root; *G*, conducting vessels of scutellum; *H*, place of attachment; *I*, digestive cells of scutellum; *J*, *K*, starch.

seeds for their propagation should not be allowed to go to seed; and the greater their ability to grow after lying in the ground for a year or two, the greater pains should be taken not to allow the seeds to get into the soil.

Wheat sprouts easily after a very short period of dormancy. This makes it necessary for the farmer to protect the wheat from moisture as soon as it is harvested, lest it begin to grow before it is threshed. Wheat that has sprouted is of little value for flour on account of changes which have taken place in the food matter partly digested for the support of the young wheat plant.

201. Corn "Seed." — A grain or kernel of corn, commonly called a seed, is like a bean (1) in containing a young plant, the corn embryo; (2) in containing food for the use of the embryo when it first begins to grow; and (3) in having marks upon it. On one side of the kernel is a depression beneath which the embryo lies. Above the depression on each kernel is a slight prom-

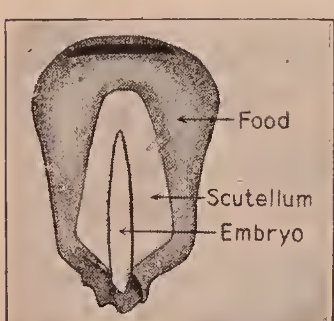

FIGURE 212. — UNSPROUTED GRAIN OF CORN.

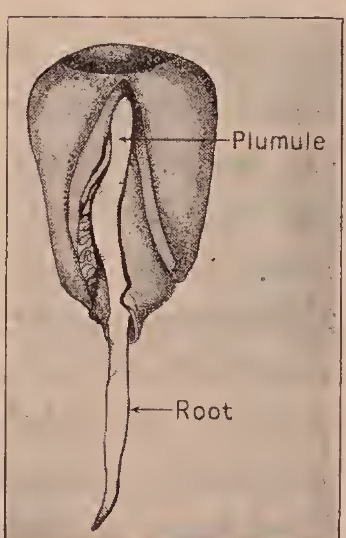

FIGURE 213. — PLUMULE READY TO BREAK OUT.

Root free and growing downward.

inence, the scar which marks the place where one thread of the so-called silks was attached. This is more prominent in pop corn. At the base is a stalk by which the kernel is attached to the cob during its development (Figure 211). Corn differs from the bean in the position of its embryo, which is at one side of the food supply. The latter is called the *endosperm* (ĕn′dō-spĕrm: Greek, *endo*, within; *sperma*, a seed). Another difference between the two is that the corn has a single modified cotyledon called the *scutellum* (skū-tĕl′lum: Latin, diminutive of *scutum*, a shield), the use of which is to absorb and digest the food and carry it to the embryo (Figure 212). The cotyledon of the corn never appears above ground. The corn embryo has its leaves rolled into a tight, pointed bud, an adaptation which enables it easily to pierce the earth above. The root is at the lower part of a short hypocotyl.

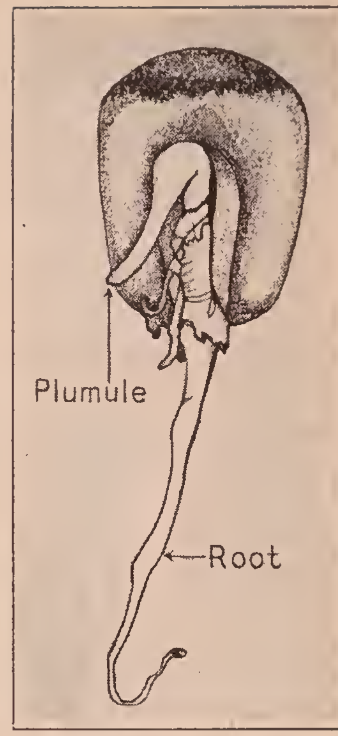

FIGURE 214. — PLUMULE FREE, BUT BENT BY ACCIDENT.

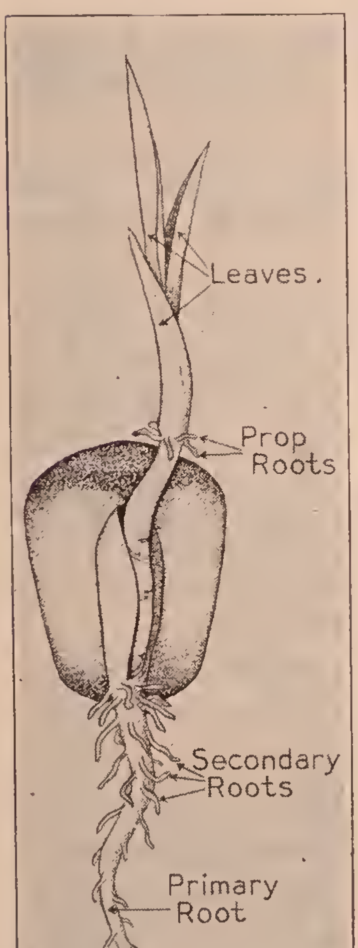

FIGURE 215. — PLUMULE UNFOLDING.

Root system developing.

As the corn has but one cotyledon, it belongs to the class of plants known as monocotyledons (mŏn-ō-kŏt-y-lē′-dŏn: Greek, *mono*, one; *kotyledon*, socket). The bean, having two cotyledons, belongs to the class dicotyledons (dī-kŏt-y-lē′dŏn: Greek, *di*, two; *kotyledon*, socket).

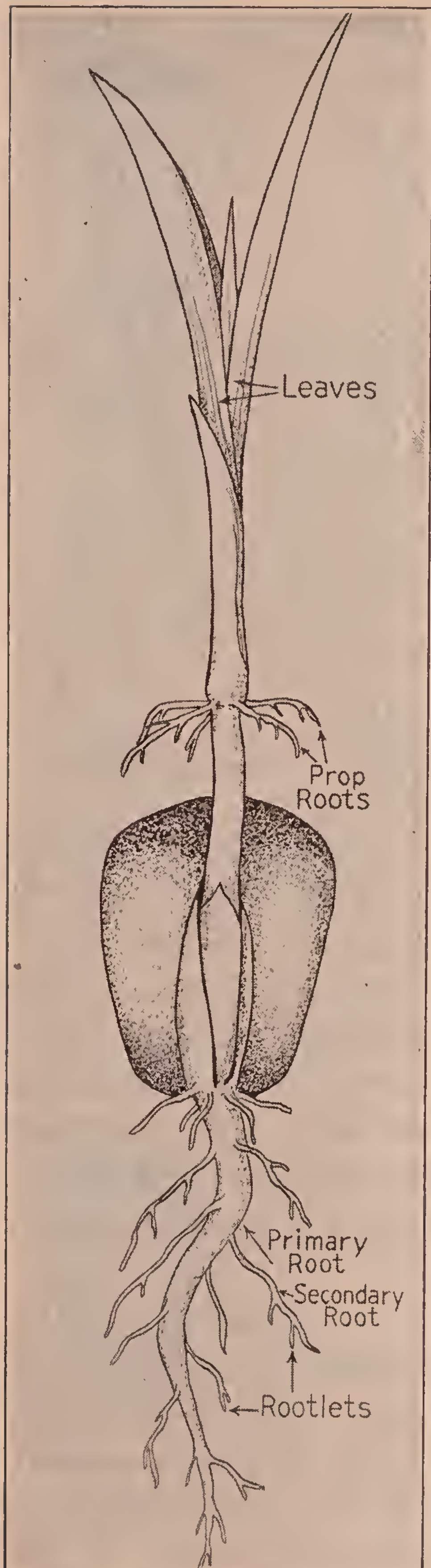

FIGURE 216. — ADVANCED CORN SEEDLING.

LABORATORY STUDY OF CORN

Draw a grain of corn, broad end up, with the side showing the depression towards you. Label (1) *silk scar* on one side of top; (2) *scutellum* (under depression); (3) *stalk* by which it was attached to the cob (hilum?).

Cut lengthwise a kernel that has been soaked for half a day. Label (1) *embryo,* young plant; (2) *scutellum* (cotyledon) lying under embryo; (3) *endosperm,* store of food on which scutellum rests; (4) hard outer covering. Cut a kernel crosswise. Draw it, and label the parts as above.

Remove the embryo. Draw. Label plumule and root. Remove the scutellum. Draw.

Remove the scutellum from each of several grains of corn when softened by soaking. Remove some of the white part of the grain. Apply the test for starch and decide whether the white part of a corn grain contains much starch. Now place a thin layer of moist corn starch in a watch glass and upon it lay several scutella. Cover with a bell jar and set in a warm place overnight. Then test with Fehling's solution. What change has taken place? What is the name of the process which changes starch to sugar? Invent an experiment to show the same change without removing the scutellum from the grain. (Hint, use wheat or oats.)

Examine seedlings you can find in garden or field and classify them as monocotyledons or dicotyledons.

202. Classification of the Common Seeds. — The comparative

study of the bean and corn seeds shows the important parts of seeds and explains the chief differences between them. Some common seeds are classified as follows: monocotyledons, *e.g.* corn, grass, wheat, barley, rye, oats; dicotyledons, *e.g.* bean, squash, morning glory, tomato, radish, and beet.

LABORATORY STUDY OF BEAN

Draw a bean in an upright position, holding the side towards you that has the hilum (a mark) on it. Label *hilum*. Near one end of the hilum is a small dot, the *micropyle*. Around the outside of bean, lengthwise, is a band or ridge, the *raphe*, ending at the hilum. Label micropyle and raphe. Split a soaked bean along the back. Draw the two parts. Label them *cotyledons*. On one of them is the *embryo* or young plant. Draw and label: (1) the pair of small, white leaves, the *plumule* or seed bud of the new plant; (2) the *hypocotyl*, below the plumule, from which stem and roots will grow; (3) *testa*, the hard covering.

Note. — Beans for class work should be soaked overnight at room temperature or for two hours in warm water.

Beans should be first soaked for several hours, then planted about a week before the lesson on seedlings.

Remove most of the cotyledons of a bean embryo. Place it in the earth or damp sawdust beside one which has whole cotyledons. Make sketches at each laboratory period to show the difference. What does this experiment show? Repeat the experiment with other seeds.

SUGGESTIONS FOR HOME WORK

Place a few beans in dry sand in a warm room. Why do not the beans grow and sprout? Place others in water in a warm room. What happens? Place other beans in moist earth (*a*) in a warm room; (*b*) in a cool place. Examine in a few days. These several experiments show the influence of temperatures, soil, and moisture on the sprouting of beans. Heat a few beans in an oven for 30 minutes and then place them in a warm, moist soil. Why do they not grow? Soak beans for 24 hours. Remove the testa and place them beside dry beans for a few days. What happens? This experiment illustrates one use of the testa.

Remove most of the endosperm from a few kernels of corn. Plant these and compare the seedlings from time to time with those from whole kernels planted at the same time in the same dish.

Place a box of soil in a warm room and keep it moist. Observe how many kinds of seedlings grow and how each gets out of the testa. How many kinds of seedlings do you find growing in your yard or garden?

203. Kinds of Foodstuffs Found in Seeds. — In the bean seed, two kinds of foodstuffs are stored, namely carbohydrates and proteins. Carbohydrate (see page 13) is the name of the foodstuff which includes the starches and the sugars. Protein (see page 14) is the name given to the foodstuff found in such foods as lean meat, cheese, and the white of egg. Beans contain more protein than any other seeds.

Corn contains starch, sugar, and oil. Flaxseed and castor beans contain much oil.

204. Foodstuffs in the Bean. — The presence of different kinds of foodstuffs may be shown by applying the following (chemical) tests. Boil beans until they are soft and then place a small portion of them in a test tube. Add water and heat. Put in a drop of iodine. If starch is present, the mixture will turn blue in color. Add strong nitric acid to a second portion in a clean test tube, boil and cool. If protein is present, the mixture will be a clear yellow color which will become orange if ammonia is added. To a third portion add Fehling's solution[1] as a test for sugar. If the latter is present, the mixture will become dull orange when heated. Test uncooked seed for oil (1) by heating it over a lamp on a sheet of linen paper; (2) by soaking it overnight in ether. (This must not be near a flame at any time.) If oil is present, it will show on the paper as a clear spot, and in the second test the oil will appear on the surface of the ether in the test tube.

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[1]

1.	Copper sulphate	9 grams
	Water	500 cc.
2.	Rochelle salts	49 grams
	Caustic potash	30 grams
	Water	250 cc.

Take two volumes of 1, and one of 2, and add to the mixture 2 volumes of water. Do not mix 1 and 2 until ready to use.

205. Where Foodstuffs Are Stored in Seeds. — In the bean, we have seen that both carbohydrates and proteins were stored in the cotyledons, evenly distributed, so far as we can discover. In the endosperm of a corn grain, the carbohydrates are under the scutellum, and the proteins in a distinct layer outside of the carbohydrates, covered by the flinty outside coat of the grain (see Figure 211).

206. Digestion of the Food in the Seed. — It may appear strange that the growing bean plant lives upon the food stored in the cotyledons and yet such is the case. But this food must undergo a real digestion before the bean embryo can use it. We do not know just how this digestion takes place in the bean, but in the corn, as we have learned, there is a special structure, the scutellum, which helps to digest the food in the endosperm. This corn scutellum may be removed from the corn seed and made to digest other kinds of starch, for instance, that obtained from a finely grated potato. To show the action of the scutellum on potato, this should be kept warm and moist for several hours, after which the digested starch may be tested for sugar with Fehling's solution. When scientists learn more about the digestive processes of plants they will probably find that they are similar to the same processes in animals.

207. Respiration. — Germinate a handful of soaked peas or other large seeds in a bottle with a wide mouth. Fit the bottle with a rubber stopper with one hole in it. Bend into U shape a glass tube of suitable size to fit the hole, but with one arm longer than the other. Insert the short arm just through the stopper, and let the longer one dip into a beaker containing lime water. Set aside overnight. What is the appearance of the lime water? What gas causes this appearance? Where does it come from? Why are seeds used in this experiment? (Answer after studying photosynthesis.)

Boil a few ounces of water to drive out all the air. Cool it. Place some seeds in it and pour linseed oil over the top

of the water to shut out air. Set aside and examine from time to time. Do the seeds sprout? Why?

Describe all the experiments above, making sketches of all the apparatus used.

Plant a seedling in damp sawdust with its plumule up and its roots down. Plant another beside it in any other position. After a day or two examine them all. What direction does the root always tend to take? the plumule?

Place a seedling in a jar before a window. What direction does it take? Turn it around. What happens after a few hours? Try the same experiment with an older plant. Which turns more quickly? Describe these experiments and invent others to show the same thing.

SUMMARY

The seed contains a new plant and food for its early life. The hypocotyl is the part of the plant (embryo) that helps it to get out of the ground. Growth of a seed depends on air, warmth, moisture, and on the food stored up in the cotyledons. Man uses the seeds for food because they contain starch, sugar, protein, and fats.

QUESTIONS

Name the parts of a seed. Name the adaptations of a seed. What is dormancy? viability? How can you show what conditions are necessary for germination of a seed?

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Ovule to Seed.
Bessey, College Botany, pages 286–288.
Snyder, General Science, page 105.
Bergen and Caldwell, Practical Botany, pages 21–23.

Seeds and Seedlings.
Snyder, General Science, pages 202–206.
Bergen, Foundations of Botany, pages 5–13; 14–24; 25.
Bergen and Caldwell, Practical Botany, pages 136–145.
Gibson, Sharp Eyes, pages 23–29.

PRACTICAL APPLICATIONS

208. Seed Selection. — Farmers who try to secure full returns for the labor expended make it a point to select seed carefully. In several states granges and other organizations offer courses of instruction as to what constitutes good seed and form clubs among the boys and girls who compete for prizes for yields of superior quantity and quality from selected seed.

Testing of Seed. — The appearance of seed alone, however, is not a sufficient basis for the production of a full crop, so it must be tested for its viability. There are many methods of making these tests, depending on the size of the seeds and the number to be tested. Anyone can perform the tests for himself who can provide suitable growing conditions for the seeds (see page 227). It is essential to success that accurate records be kept of the results of the experiments and tests.

Preparation of Soil. — Having learned from tests that he has seed which has a high percentage of viability, the farmer's next problem is how to prepare the soil for it. The preparation consists in making it fine and soft by plowing and harrowing, and in mixing the fertilizer thoroughly with it. The depth to which soil is plowed and the degree of fineness to which it is reduced are determined by the kind of crop to be planted and the amount of cultivation it can receive while it is growing. In any case, it must allow the roots to penetrate it easily, for it is from the soil that the roots gather moisture and food material for the plant.

In addition to knowing that his seed will grow and that the soil is in proper condition for it, the farmer must know *when* to plant his crops. Some will not be injured by light frosts, while others must not be planted till all danger of frosts is past. He must know too, how deep to plant his seeds, and how firmly to press the soil over them in order to have

them germinate normally, as well as how many to plant in a given area.

When his crops are above ground, many of them, corn for example, must be cultivated. In cultivating, three objects are kept in view, (1) to keep the soil loose enough for the roots to penetrate it easily, (2) to conserve moisture, (3) to kill weeds.

Thinning and Transplanting. — Crops like garden vegetables will not grow to full size unless each one has sufficient room. On the other hand, a greater yield can be secured by transplanting to fill all vacant spaces. Transplanting tomatoes, peppers, and other plants grown in greenhouses makes it possible to secure ripe fruit earlier than if they were first planted out of doors after danger of frost.

CHAPTER XVII

THE FRUIT

209. Definition. — The fruit of a plant is the final result of the work of the flower. In its simplest form it is the ripened ovary and its contents including the seed or seeds. In some cases, however, it involves accessory parts of the flower as well, especially the receptacle. The wall of the ovary in a fruit is called the pericarp. Peculiarities of the pericarp will be mentioned in connection with different kinds of fruit.

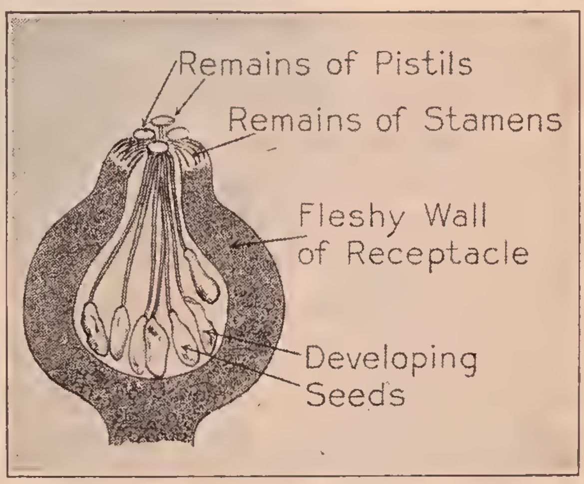

FIGURE 217. — DIAGRAM OF FRUIT OF ROSE.

The fruit is of use to a plant in two ways, (1) in protecting the seeds during their development, as in the bean, or during their period of dormancy as in the nut, and (2) in helping to distribute the seeds after they are matured, as in the dandelion.

The fruit of most plants is the part that is of greatest use to man, furnishing him most of the necessaries in the way of food, and many of the luxuries.

LABORATORY STUDY

Study of an Orange. — Examine the stem end and note the remains of the calyx. How many sepals had the flower? Remove it. How many dots do you see? These represent the ends of the vascular bundles which supplied food to the growing fruit. Examine the opposite

end for scar showing where the pistil was attached. Scrape the skin or pinch it, and note the oil which shows as a yellow, odorous liquid.

NOTE. Place a drop of this oil on linen paper. Note the spot it leaves. After a day examine the paper. Is the spot still visible? Oils that evaporate, leaving no spot, are called *volatile* or *essential* oils. Place peanut, Brazil nut, or castor bean on a linen paper. Heat till a clear spot shows. Lay aside and examine from time to time. Does the spot disappear? Oils that do not evaporate are known as *true oils*.

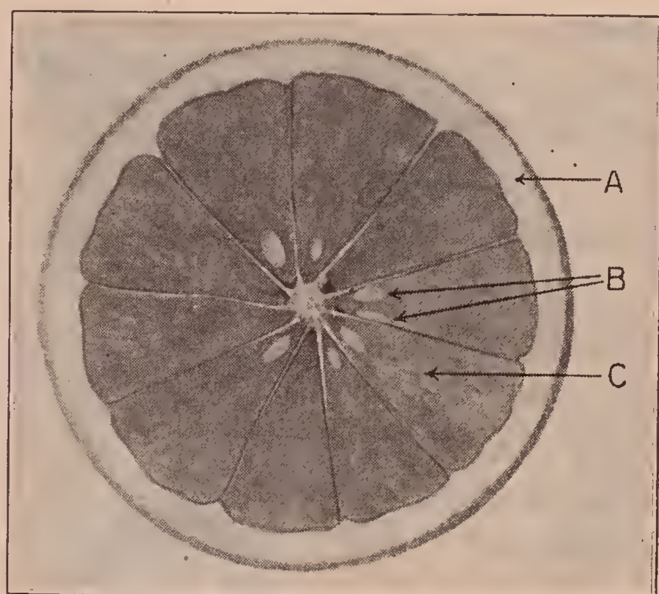

FIGURE 218.—CROSS SECTION OF ORANGE, A BERRY.

A berry in the botanical sense is a fruit in which both exocarp and endocarp are fleshy or juicy, although the seeds themselves, imbedded in the flesh, may be hard or even stony. Oranges, cranberries, huckleberries, currants, grapes, and tomatoes are true berries. *A*, rind; *B*, seeds; *C*, pulp.

Make a cross section through the middle of the orange. How many distinct parts are there? Where are the seeds? Note the oil glands in the cut skin. Draw and label the parts named above.

Remove the skin from a whole orange and separate the parts. How many are there? Look for a strand of connective tissue on each one. Where do they come from? Compare the number of sections with the number of vascular bundles on the stem end.

210. Study of a Tomato.—Examine the whole fruit for traces of parts of the flower. On which end are they found? How many sepals were there in the flower? Remove the stem and count the number of vascular bundles. Make a cross section through the middle. How many divisions in

the tomato? Where are the seeds? Note the mucilage with which each is surrounded. Can you see the vascular bundle which entered it? Note the very thin skin. Draw and label all.

NOTE. Tomatoes can be obtained at any time of the year. Canned, unpeeled tomatoes will serve the purpose. Small ones are as satisfactory as large ones.

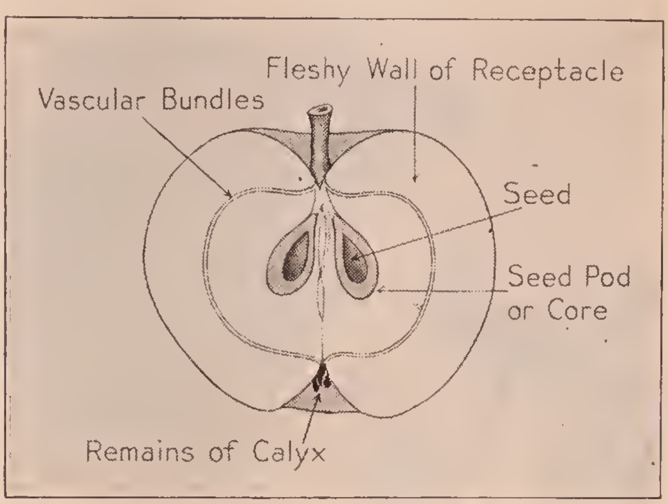

FIGURE 219.—VERTICAL SECTION OF APPLE, A POME.

The pome, apple, quince, pear, etc., is a fleshy fruit in which the receptacle becomes consolidated with the pericarp. The receptacle and exocarp become fleshy while the endocarp becomes papery and incloses the seeds, thus forming the *core*. The fruit of the rose, called a "hip," shows the relation of parts. (Figure 217.)

211. Study of an Apple. — Examine the whole apple. On the blossom end find the old sepals. How many? In the end of the stem look for vascular bundles. Draw and label. Make a cross section through the middle. Draw. Label the seeds in the papery pod (core). How many divisions has it? How many vascular bundles, as shown by dots near the core?

Make a vertical section. Label vascular bundles when seen, stem, fleshy wall of receptacle, and remains of sepals. Are the remains of sepals on the same end in the apple as in the orange?

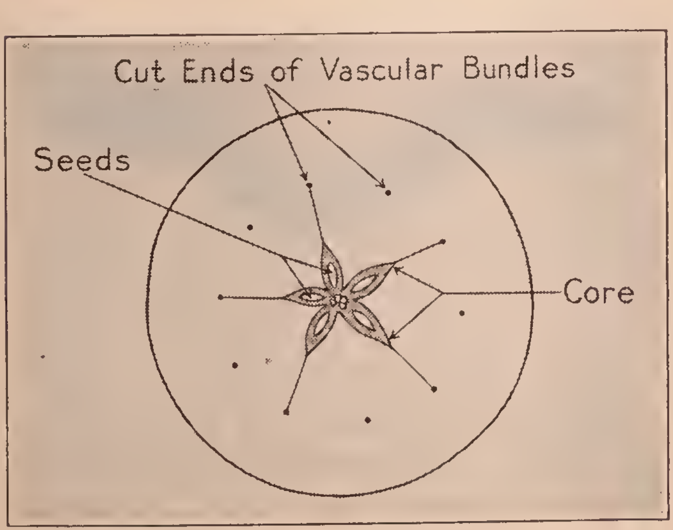

FIGURE 220.—CROSS SECTION OF APPLE.

Other Studies. — Review the study of the corn grain, and compare with grains of wheat. Where is the scutellum

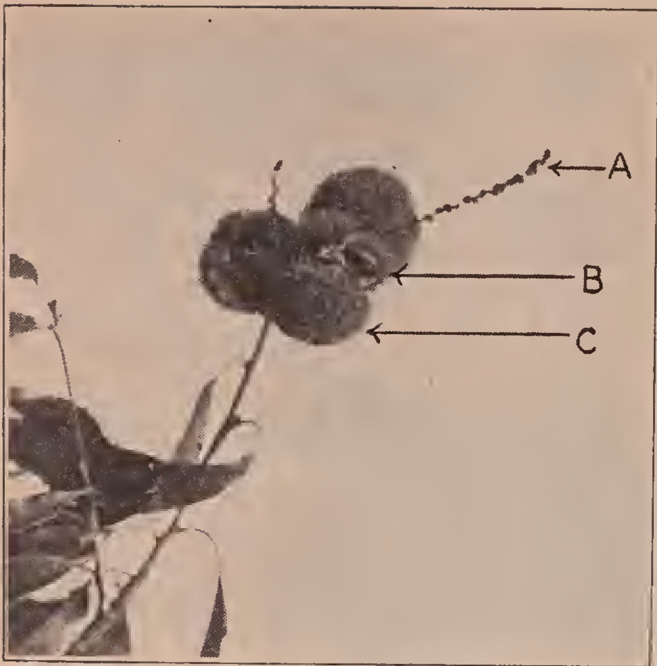

FIGURE 221. — CHESTNUT, A DRY FRUIT.
A, remains of staminate flowers; *B*, nuts; *C*, bur.

in the wheat? Draw and label.

Draw a pod of bean or pea showing valves, seeds, remains of sepals, and place where pistil was attached. Examine fruit of dandelion, milkweed, and other weeds as you find them.

HOME WORK

See how many kinds of fruits you can find. Make a list of fruits obtained. After studying orange in laboratory, study apple, tomato, and other fruits at home as suggested in the text.

212. Classification of Fruits. — Fruits may be grouped under two heads, (1) fleshy and (2) dry fruits. Dry fruits are of two kinds, (1) those that open, dehiscent (dē-hĭs′s'nt) (Latin, *dehiscere*, to open) fruits, and (2) those that do not open, indehiscent (Latin, *in*, not; *dehiscere*, to open). Indehiscent fruits have been formed by the thin wall (pericarp, the wall of the ovary, matured) adhering closely to the seed, much as if a pod containing a single seed grew so firmly to it that it could not open.

A grain of corn or wheat is a typical indehiscent fruit. The pericarp, though very thin, is hard and flinty, furnishing effective protection to the inclosed embryo and food.

FIGURE 222. — SAMARA, THE WINGED FRUIT OF THE MAPLE.
A dry, indehiscent fruit, adapted to distribution by the wind.

The following table shows the main kinds of each group:

DRY:

Dehiscent:

Pod	Follicle
Loment	Silique
Capsule	

Indehiscent:

Nut	Grain
Samara	Akene

FLESHY:

Berry	Pome
Drupe	Multiple
Aggregate	Accessory

FIGURE 223. — LEAF, FLOWERS, AND FRUIT OF WITCH-HAZEL.

This picture was made in October when the shrub blossoms. It is pollinated by insects that fly in the late fall. The fruit remains dormant during the winter and starts to develop in the spring. By fall it is mature and the exploding fruit scatters the seed. The name witch-hazel is said to have been given because it seems to fruit first in the spring and then blossom in the fall. It was supposed to be possessed by witches; hence the name. The name was given way back in the time when ignorant people explained things they didn't understand by ascribing them to the witches.

Dehiscent fruits show many adaptations, most of which are based on some peculiarity of the pod. Take the bean for example. The pod is elastic. When it dries this causes it to split, then to curl up, throwing the seeds out by force. Another adaptation is that the funicle (see § 193) dries up and falls off when its work is done, leaving the seeds free in the pod. A pod which has elastic tissue is the wild cucumber which forces its seeds out violently. Still another is the witch-hazel. A pod which explodes violently is that of the jewel-weed which requires only a touch to set it off, scattering the seeds far and near.

A capsule differs from a pod chiefly in having more than one chamber in immature stages. A capsule usually splits

in several places, one for each chamber of the ovary, an adaptation for releasing all the seeds. Thus the violet spreads its valves wide open and does it suddenly, by this means throwing its smooth, hard seeds to a distance of several feet. The capsule of the poppy opens at the top by a number of chinks which appear just under the projecting lid. The capsule remains upright on a stiff stalk, which tips this way and that when the wind blows, scattering the small seeds. The plantain has a capsule which opens with a lid exposing a mass of seeds which are easily blown about by the wind. The special adaptations of the plantain are that its stalk remains upright after snow falls and that the lid does not fall off until the ground is covered with snow. The light seeds in great numbers are blown on the snow and carried long distances when it is smooth. These adaptations cause plantain to become a troublesome weed. Purslane, another weed, opens its capsule in the same way. So does portulaca, a cultivated plant. This form of capsule is called a pyxis or pyxidium.

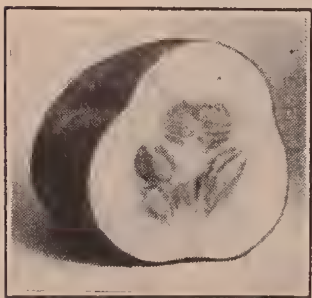

FIGURE 224.—CROSS SECTION OF CUCUMBER, A PEPO. (A FLESHY FRUIT.)

Note the three seed chambers.

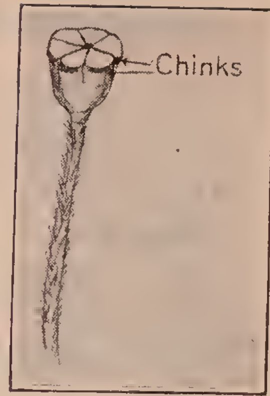

FIGURE 226. — CAPSULE OF POPPY.

This contains several chambers and numerous small seeds which are shed through the chinks when the wind tips the stiff stalk.

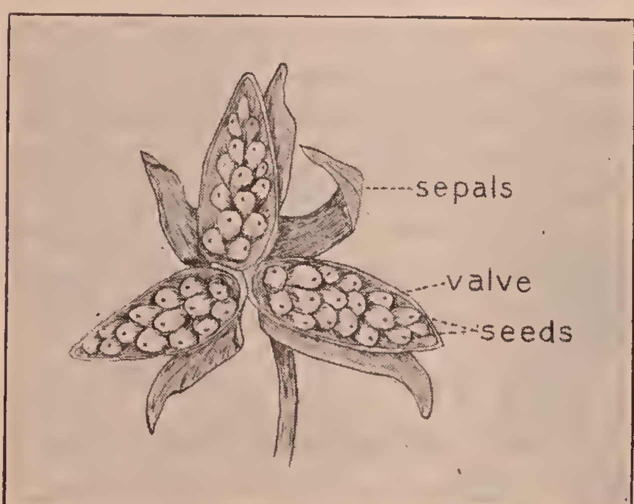

FIGURE 225. — CAPSULE OF VIOLET.

A dry, dehiscent fruit formed from a compound carpel. Note the three chambers and the numerous seeds. The drying of the capsule causes the seeds to be pinched off and sent a foot or two away.

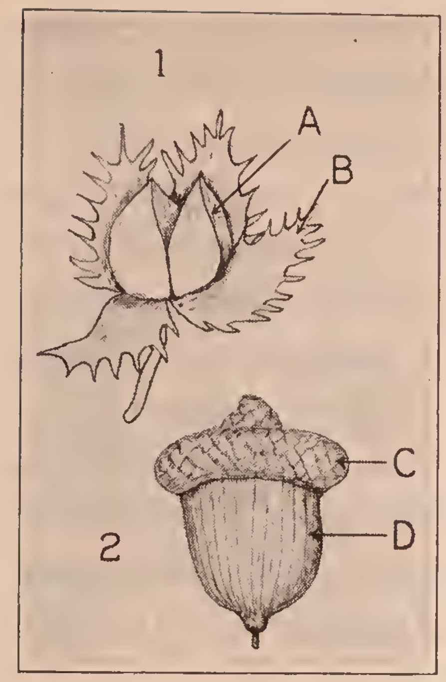

FIGURE 227. — DRY FRUITS.

1. Beechnut. The seed is inclosed in the pericarp (*A*), and the whole surrounded by the bur (*B*), which was formed from the involucre.

2. Acorn. *C*, cup formed from involucre; *D*, seed inclosed in pericarp.

The adaptations of fleshy fruits are (1) a sour or bitter taste during development. This prevents their being eaten before the seeds are mature. (2) Edibility when ripe. This insures their being eaten by some animal, sometimes without the seeds, which are likely to be dropped some distance from the plant which produced them; or seeds and all, in which case the undigested seeds are passed off with other wastes, often very far from the parent plant. Cedar trees, wild fruit trees, blackberry bushes, and asparagus growing by fences or in the crotches of trees show the effectiveness of this form of adaptation.

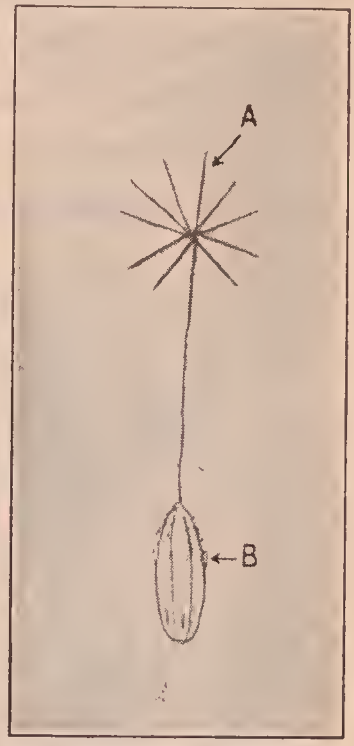

FIGURE 229. — AKENE OF DANDELION.

A, pappus; *B*, fruit.

FIGURE 228. — VERTICAL SECTION OF PEACH, A DRUPE.

Note the stone in the center in which the seed is inclosed. The white fibers are vascular bundles.

In fleshy fruits, most of the modifications are associated with the pericarp which develops in zones or layers. The group of fleshy fruits known as "stone fruits" or drupes has a thick fleshy outer portion (exocarp) which incloses the inner stony part (endocarp).

Blackberries and raspberries are collections of small drupes which make up an *aggregate* or *collective* fruit. In the case of raspberries, the fruit separates from the receptacle which remains on the stem. In blackberries it does not separate, but the receptacle is removed from the stem as part of the fruit.

Accessory fruits are fleshy fruits in which the pericarp may be seated upon the receptacle or it may be inclosed by it. The strawberry has a fleshy receptacle in which the true fruits, akenes, lie in depressions.

FIGURE 230. — SEED DISPERSAL OF MILKWEED.

The pod opens, exposing the seeds. The air causes the long, silky hairs attached to each seed to dry and spread, helping to force the seeds from the pod, and enabling the wind to carry them long distances.

Multiple fruits are those in which two or more separate flowers may blend into a single mass, as in the mulberry and the pineapple. Pineapples, through long cultivation, have lost the habit of producing seeds.

213. Seed Dispersal. — Before any fruit has fulfilled its function, it must scatter the seeds it contains. This is necessary for three reasons, at least. (1) There would be too much competition if all were dropped near together; (2) there would be too slow progress, for the soil near the parent might be depleted, and the new plants could not grow as well there as in fresher soil; and (3) there would be too great a chance of extermination if all were dropped near together, for

some one unfavorable condition might kill them all. In order to scatter seeds a plant makes use of wind, animals, and water as distributing agents, and of such mechanical devices as exploding pods. To be distributed by the wind, a seed or a fruit must be light. This is brought about in some plants by plumes as in the case of the akene of the dandelion, thistle, and clematis, by the down on a milkweed seed, and by the wings on the fruits of the maple and elm. (Review § 209.) To be carried by animals, the adaptations may be of two kinds — either they must have hooks to catch on or they must be edible. The burdock and beggar's tick represent the first kind of adaptation, and the fleshy fruits the second. In some cases only the fruit is eaten, as with peach, plum, etc., and the seeds dropped; and in other cases the seeds and all are eaten, but are not acted upon in the digestive tract, and so are dropped far from the spot where they grew, as with berries, apples, pears, etc. (Review § 212.)

FIGURE 231. — FRUITS DISTRIBUTED BY ANIMALS.

A, avens; *B*, hound's tongue; *C*, cocklebur; *D*, burdock.

To be carried by water, the adaptations must be such as will insure buoyancy and the ability to withstand decay. Both are well illustrated by the coconut, and the former by the cocklebur. To be distributed by being forcibly expelled, the fruits must have elastic tissue. The jewelweed or touch-me-not illustrates this, as does witch-hazel, wild cucumber, and violet (see Figure 225).

Special devices for wind distribution are found in the Russian thistle and in tickle-grass, a common garden weed. In the former case the whole plant breaks off at the level of the ground, and is blown about by the wind, fruits and seeds being broken off and scattered as it rolls along the ground. This is one of the worst weeds of sections of the western states. In tickle-grass, only the panicle is broken off, but the result is the same.

Besides the distribution of seeds by means of scattering the fruit or the seeds, plants have other means of propagating themselves which will be spoken of as they occur. The main dependence for keeping up the race, however, in most plants, especially the wild ones, is the distribution of its seeds. The fruit of a plant, so far as its relation to the plant that bore it is concerned, is simply a device for securing the distribution of the seeds it contains.

PRACTICAL APPLICATIONS

214. Fruit. — The fruit-grower's success depends largely upon his knowledge of the proper time for spraying his trees in the spring. (Review § 28.) He must wait till the bees have finished their visits, for he needs the help they give in pollinating the flowers. He must use a poison spray soon enough to kill the codling moth and thus prevent her laying eggs in the flowers or in the young apples, for this insect destroys much fruit. The best time is when the petals are falling, for pollination is then accomplished and there is no danger of killing the bees, yet the harmful codling moth is kept from injuring the fruit. (Review structure of honey-bee and life-history of codling moth.)

To secure the largest possible crop of strawberries, the gardener must be sure he has varieties that produce both stamens and pistils or at least that he has a sufficient number of staminate plants to produce pollen for the plants which bear only pistils.

He should know, too, that the so-called false blossoms of the cucumber bear the pollen, without which the cucumbers will not develop in the pistillate flowers.

The farmer should know that corn of different varieties like sweet corn and popcorn should not be planted in adjoining fields lest undesirable cross-pollination occur. Ears resulting from such pollination are uneven in size and show grains which differ in color from most of the other kernels. These are hybrids. He has probably learned from experience, however, that closely planted rows of corn in a field produce fuller ears than stalks standing alone. This is due to more thorough pollination.

Fruit packers have learned that very careful handling is necessary in picking, sorting, and shipping fruit in order that the skin may not be broken. Broken skin admits bacteria (see page 309) which soon cause decay. Cold storage checks the growth of bacteria if any are present.

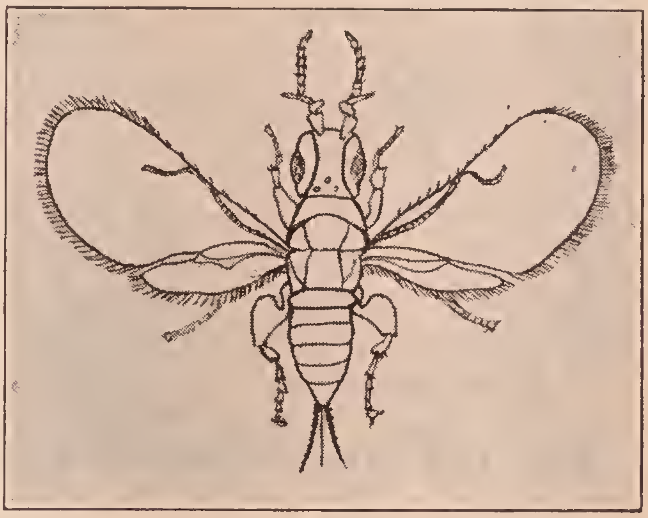

FIGURE 232. — FIG-WASP (much enlarged).

For many years Smyrna has been the source of the fig supply of the world. The fruit-growers of California, seeing no reason why figs should not grow in that state, imported trees from Smyrna. Although these trees produced many blossoms, none of them matured into fruit. It has been customary since the time of Aristotle to hang branches bearing the wild, inedible fig in the Smyrna fig tree when it was in blossom. This wild fig, known as the caprifig, harbors the parasitic fig-wasp (Figure 232). The caprifig produces three kinds of fruit, spring, summer, and fall. The fig-wasp lays its eggs in the flowers of the caprifig (Figure

233) and as it crawls about, its body becomes covered with pollen which is carried from flower to flower. Only the summer and fall flowers of caprifig produce pollen, and only the fall caprifig matures pollen at the time when the Smyrna figs are in blossom. The fig-wasp, seeking suitable flowers in which to deposit eggs, enters the Smyrna fig and leaves pollen from the flowers of caprifigs on the stigmas, thus fertilizing the Smyrna fig flowers which can now develop.

It took many years of experimentation to discover all these intricate relations existing between the wild and the cultivated fig, and their dependence upon a certain insect to carry pollen. This is an extreme illustration of the interrelation between two closely related plants and a parasitic insect.

FIGURE 233. — VERTICAL SECTION OF CAPRIFIG. Note opening at top, and flowers inside.

All these peculiar relations, however, had to be worked out by scientists before the fig industry could become a success in California. Now Smyrna fig trees, wild caprifigs, and the fig-wasp have all been introduced, with the result that California's fig-raising industry is a success.

215. The Uses of Fruits to Man. — In speaking of the uses of fruits to man, it must be remembered that all the grains are fruits and that many so-called vegetables are fruits, as the tomato, the squash, and the cucumber.

The most valuable source of food in the world is found in the cereals: wheat, oats, rye, rice, barley, and others. Nearly half of the population of the globe depends on rice for its principal food. Rice is the only one of the cereals that is commonly eaten entire. The others are usually ground and made into bread. The importance of bread as an article of food is shown by the term, "the staff of life," which is often applied to it. In the famine-stricken regions

during the late war, the hungry cried for bread more than for any other article of food. A diet consisting of bread and nuts furnishes all the elements of food.

Modern methods of grinding the cereals detract from their healthfulness as food because, in the refining process, all the coarser parts are removed, some of which contain substances, *vitamines*, essential to stimulating digestion.

Not only are the cereals the most important article of food, but they are the basis of a great part of the world's work. The raising of cereals, their preparation for food, and their distribution give employment to a greater number of persons than any other industry. Much more attention is now given to agricultural education than formerly, because its importance as an industry is better appreciated. Besides supplying man with food directly, many cereals are used to feed the animals which he raises for the meat, milk, butter, cheese, and eggs which they produce. Man's beasts of burden live largely upon cereals too.

The articles of food commonly known as fruits, — apples, oranges, berries, bananas, and others, — are valuable, their chief use being to supply variety to the diet. The fruits obtained from the vegetable garden, — tomatoes, cucumbers, squashes, egg-plant, melons, and others, — furnish some foodstuffs. Their main value, however, is to supply the bulk so necessary to the proper working of the organs of digestion. Incidentally, they add variety, and serve to make other food more appetizing.

216. Uses of the Terms Fruit, Seeds, etc. — It will be evident by this time, that the words fruit, seeds, and nuts have a different meaning in botany from their ordinary use. The term "seed corn" and "seed wheat" used by farmers is correct in the sense that it indicates the corn or the wheat which is planted or sowed to produce a new crop. The so-called Brazil nut of commerce is in reality a seed. The fig is a "fruit" composed of a thickened and hollow receptacle,

the end of a branch, on the inside of which are produced the real fruits commonly known as seeds.

HOME WORK

What articles of food on your breakfast table were fruits? Where were they raised? How were they brought to your home? What kinds of food were furnished by each? Look up the population of China, India, and Japan for the year 1915 or later. Most of these people live chiefly on rice. How does that compare with the number in the northern countries of Europe and the United States who live largely on the other cereals?

SUMMARY

Reproduction is the ultimate object of the plant's life, because it is the vital process which produces the seeds by which the plant is enabled to insure a new generation.

The fruit serves to protect the seeds while they are growing, and to secure their distribution when they are ripe. The fruit of many plants is the part most useful to man, furnishing him the necessaries in the way of food, and many of the luxuries. Man has been able in some cases to improve the quantity and the quality of fruits for his own use.

QUESTIONS

What is a fruit? What is its function? Name the different kinds of fruits and give an example of each.

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Bergen, Foundations of Botany, pages 217–227.
Coulter, Plant Life and Plant Uses, pages 62; 325–335, 353–356.
Abbott, General Biology, page 278.
Bessey, College Botany, pages 324–326.
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Gibson, Sharp Eyes, pages 4, 5; 150–155; 170–174; 205, 206.

CHAPTER XVIII

THE ROOT

The root is the part of the plant which grows from the bottom of the stem. The roots of most plants are underground. Roots are the part of the plant that (1) gather water and food material from the soil; (2) that hold the plant firmly in the soil, and (3) in plants that live over the winter, store food to be used the following year.

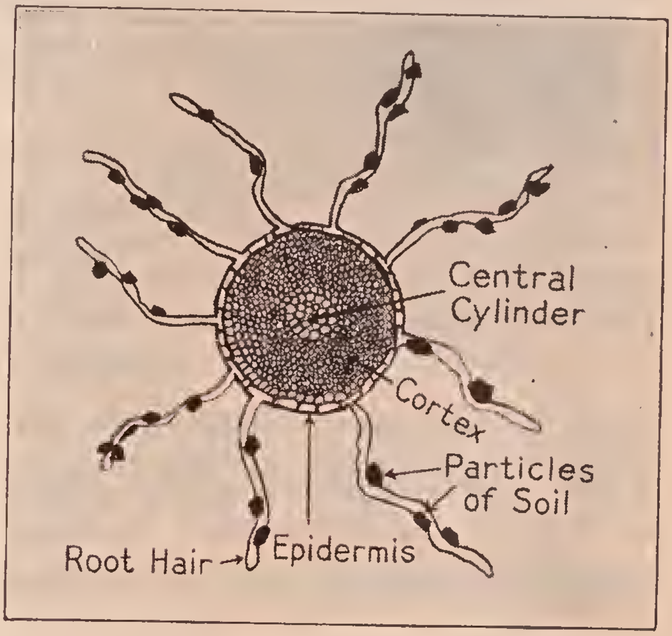

FIGURE 234. — CROSS SECTION OF ROOT WITH ROOT HAIRS.

Note the relation of the hairs to the epidermal cells. Note also the irregularity caused by growth among the particles of soil, some of which still adhere.

217. Structure of a Root. — The outer part of the root is covered with a layer of epidermis called *dermatogen* (dẽr-măt′ō-jĕn: Greek, *derm*, skin). Inside of this is a region called the *cortex* or *periblem* (pĕr′ĭ-blĕm: Greek, *peri*, around) which surrounds the innermost region called the central cylinder or *plerome* (plēr′ōm: Greek, *plēre*, full). Near the tip, below the central cylinder, is a rapidly growing tissue, the *meristem* (mĕr′ĭ-stĕm: Greek, *meristos*, divided), from which all the other parts develop. Over the end of the smaller roots is the root cap or *calyptrogen* (kăl-ĭp′trō-jĕn: Greek, *kalyptros*,

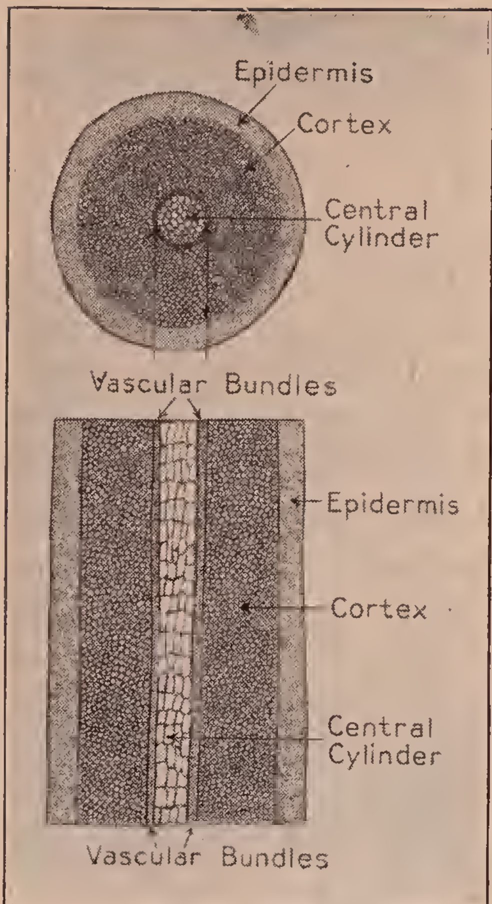

FIGURE 235.— CROSS AND LONGITUDINAL SECTION OF ROOT.

hidden). Each of these parts of a root adapts it to do its work. The epidermis keeps it from drying. The region of the cortex contains the conducting vessels which carry water to the stem and digested food back. The central cylinder is the region where most of the food is stored. The root cap protects the tender end of the root from injury as it pushes through the soil, and the meristem tissue provides for renewing all the regions of the root, and increasing their size. Besides the main root, there are many smaller roots which divide still further into rootlets. The root and its divisions underground may be compared, in a general way, to the stem, branches, and twigs aboveground.

218. Root Hairs. — Root hairs are found a short distance back from the tip of each rootlet. Each hair consists of a projection of an epidermal cell. Root hairs are very numerous. As the root grows, the hairs farthest from the tip die and are replaced by new ones nearer the tip. Root hairs greatly increase the absorbing surface of a rootlet. They attach themselves firmly to particles of soil from which they are able to take almost every trace of moisture by the process of osmosis (see

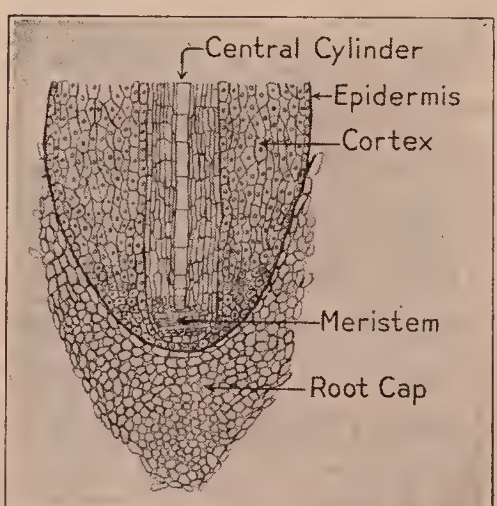

FIGURE. 236. — LONGITUDINAL SECTION THROUGH ROOT AND ROOT CAP.

page 15). They also serve to fix the plant firmly in the soil.

LABORATORY STUDY OF ROOTS

FIGURE 237. — GERMINATING WHEAT, SHOWING ROOT HAIRS.

Notice the plumule growing up and the roots down. This grain of wheat was germinated in moist air, and not in the soil. Root hairs are seldom seen in soil grown seedlings, as they are so fragile that they break off and remain in the soil when the seedling is removed.

Cut a root of carrot or parsnip lengthwise and identify (1) *dermatogen*, the epidermal covering; (2) *cortex*, the region under the dermatogen; (3) *plerome*, or *central cylinder*. Cut it crosswise and identify the same regions. Make drawings of both sections and label fully. In both sections look for rootlets and note the region from which they arise. Show this in your drawing.

Stand cut-off roots of parsnip overnight in water tinted with red ink. In what region does the color show? Make cross sections of one and longitudinal sections of the other. Draw both and describe.

Look at the roots of seedlings furnished you. How does the extent of roots compare with the parts aboveground?

Examine roots grown in a moist chamber for root hairs. Compare with one grown in sawdust or soil after it has been carefully washed. How do they differ? On what part of the rootlet are the root hairs most numerous? Where are they the longest?

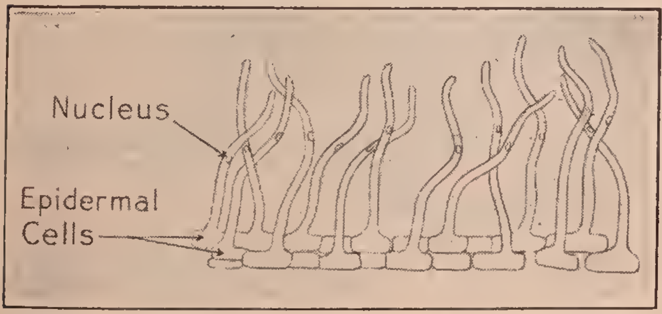

FIGURE 238. — BIT OF EPIDERMIS OF ROOT WITH ROOT HAIRS.

Mark a root with a fine pen dipped in India ink, making the marks even and close together (about 1 mm.). Examine from time to time to

determine where growth is most rapid as shown by increased distances between marks.

Test roots for the presence of starch, sugar, and protein, using the tests suggested for seeds. Make a report on what you find.

In what direction do roots usually grow? Try to make them grow in some other direction. Write what you did and show by drawings what success you had.

Draw aërial roots of an ivy stem.

Draw a cluster of fascicled roots of a dahlia or a buttercup or an anemonella.

SUGGESTIONS FOR HOME WORK

Pull weeds and examine the roots. Which have tap roots? Why do they flourish better than the plants around them?

Cut a piece of thick sod with a sharp spade or trowel. How many grass plants in a square two inches on a side? What kinds of roots has grass? Wash the dirt away carefully and measure the extent of the root system. Compare it with the part aboveground. Do the same with other plants than grass.

On how many nodes of a corn stem do prop roots grow? What is the effect of "hilling up" corn on the production of prop roots?

Place willow twigs in water. Watch the growth of adventitious roots, noting especially the root caps. Do duckweed and other floating plants have root caps? Account for what you find.

Examine a large number of roots and report.

	Roots All Underground	Roots not All Underground	Primary Roots	Fibrous Roots	Aërial Roots
Dandelion .					
Plantain .					
Carrot . .					
Dahlia . .					
Corn. . .					
Ivy . . .					

FORMS OF ROOTS

Tap or *primary* roots — adapted to penetrate the soil, deeply enabling them to secure water when plants with different roots cannot. Adapted also to the storage of food.

Fibrous roots — a great many threadlike roots which extend in all directions through the soil.

Thickened fibrous roots — a modification of fibrous.

Fascicled roots — a cluster of thickened roots for the storage of food.

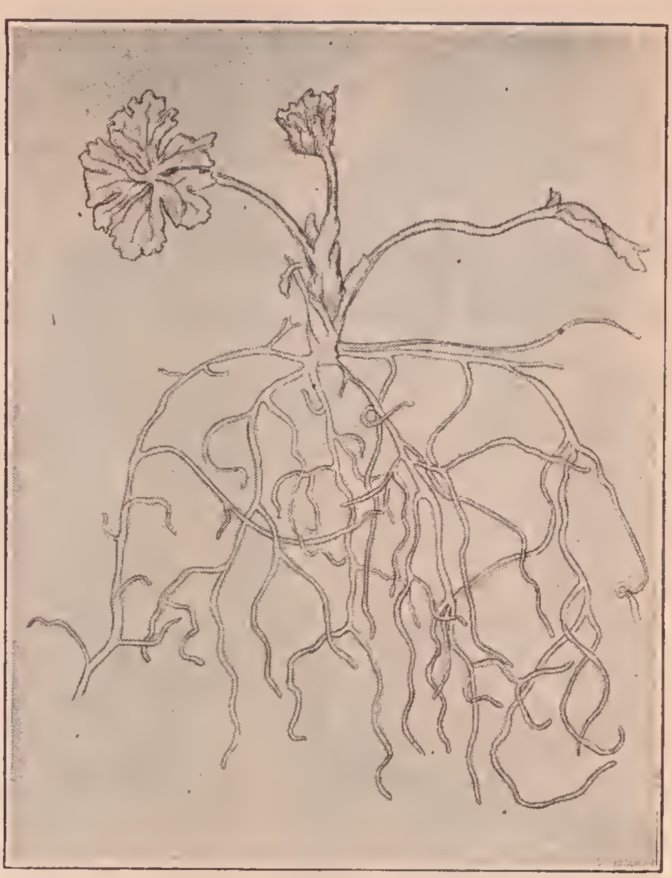

FIGURE 239. — FIBROUS ROOTS OF THE BUTTERCUP (slightly thickened).

MODIFIED ROOTS

Aërial roots for attachment. Ivy. Note how they grow from side of stem.

Aërial roots for absorbing water. Certain orchids, tropical plants which grow in the air.

Water roots lacking root cap. Duckweed.

FIGURE 240. — FASCICLED ROOTS OF DAHLIA. Used for the storage of food.

Knees — projections on roots of cypress.

Adventitious roots — those that grow in unusual positions, especially from the end of a cut stem. Geranium, willow, any "slip."

219. The Duration of Roots. — Roots which live only for a season are called annual roots, examples of which are corn, peas, beans, and other common garden plants. Those that store the food manufactured one season and use it to produce flowers and fruit the next are called biennial roots. The garden furnishes examples of these in the fleshy roots of carrots, parsnips, beets, turnips, and vegetable oysters. Roots that live from year to year, like those of trees, the dandelion, burdock, horse-radish, peony, and "pie plant" are perennial roots.

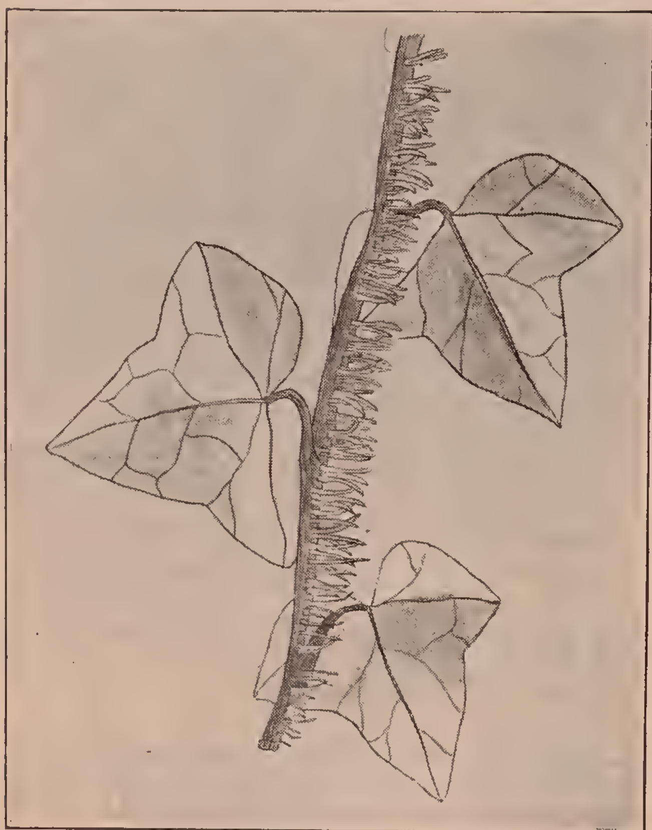

FIGURE 241. — AËRIAL ROOTS OF IVY.

These are used for attachment, growing only on the side towards the surface on which the stem lies.

220. Extent of Root System. — The root system of a tree growing in fertile soil is about equal to the parts above the ground. An oat plant has a root system the combined length of which is about 154 feet; a wheat plant has single roots seven feet long; and alfalfa an enormous root system (see Figure 244). A single root of alfalfa may extend more than 20 feet in one direction in a loose soil.

221. Specialized Roots. — The roots of the ivy which grow for attachment differ from ordinary roots not only in

their function, but in their position. They can grow from any side of a stem, enabling them to attach themselves to a surface wherever they may happen to touch it.

FIGURE 242. — TAP ROOTS OF RADISH.

All tap roots are used for food storage, and most of them are either biennial or perennial.

The haustoria by which parasite plants (see page 369) get their food from the host are modified aërial roots. They are able to take food from the stem of the host by absorbing pads, as is well illustrated by dodder.

The cypress tree, which grows with its roots submerged, has peculiar projections which extend above the surface of the water. These so-called "knees" are so modified that the roots are enabled to secure the air they need.

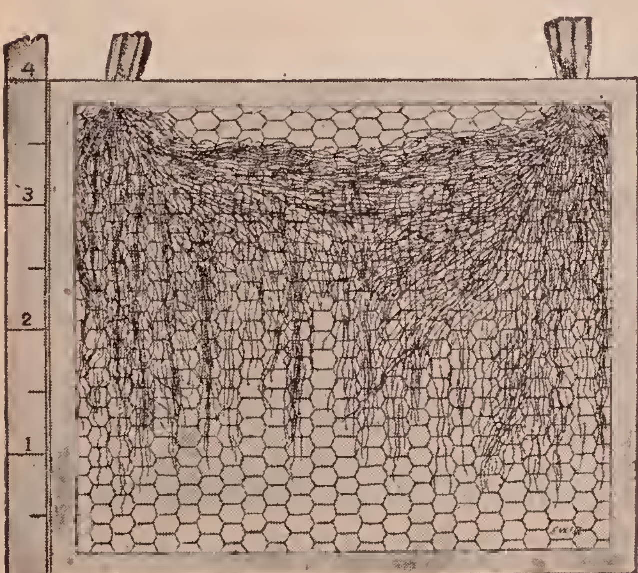

FIGURE 243. — EXTENT OF ROOT SYSTEM OF CORN 90 DAYS AFTER PLANTING.

Note how the roots of adjoining hills mingle. This shows how keen the struggle is to get water and food, and how the soil is deprived of its food contents.

The pendant roots of the tropical orchids, known as velamens, have a modified outside layer which enables them to absorb almost immediately any water which falls on them and conduct it to the central cylinder for storage. This enables the plants possessing them to live outside of the soil (see page 373, epiphytes).

Prop roots of corn grow from nodes above the soil,

which they penetrate. This is an adaptation for holding the plant more securely than the ordinary roots could do. When mature, they branch freely.

Adventitious roots are those which grow from unusual places, especially soil roots. It is the ability to form such roots that enables us to "slip" plants like geraniums, balsams, ivy, and Wandering Jew. Such garden plants as

FIGURE 244. — ROOT SYSTEM OF ALFALFA.

How far from the stem of the plant do you think the roots extended?

tomato, cucumber, squash, and others, put forth adventitious roots where their stems touch the soil, especially at the nodes in the case of the vines named. This is an adaptation which gives them a greater supply of food material near the leaves which use it, and which enables the plant to live even if broken from the main portion of the stem.

Certain cactus plants which live in the desert have roots which are twenty times as long as the parts which appear

above the soil. This enables them to absorb and to store up the scanty moisture.

222. Economic Uses of Roots.—In some plants the root is the most valuable part for food not only for man but also for his animals. Examples of this are many of the garden

FIGURE 245.—ROOT SYSTEM OF RHUBARB, A MEDICINAL PLANT.
Food is stored in the larger parts. Many of the rootlets have been broken off.

vegetables, such as carrot, parsnip, turnip, vegetable oyster, and beet. The food stored in the beet is rich in sugar, making it one of the sources of the sugar of commerce as well as a valuable food for stock. Other roots furnish substances used as medicine when they have been extracted, as rhubarb

and mandrake, while the ground root of ginger is used in medicine and in cooking. The vegetable oyster is often found growing by roadsides where its seed has been blown from gardens.

In the case of these roots, a few must always be saved to produce seeds for another crop, inasmuch as turnips, beets, carrots, parsnips, and vegetable oysters are biennials, requiring to be planted the second season, when they use food stored during the first year to produce fruit and seeds.

PRACTICAL APPLICATIONS

Anything which concerns the condition of the soil in which plants are to grow and the amount of raw material available for food-making is important because of the relation of the roots to the soil and of their function to the plant. For this reason every one who raises plants should know the habits of each kind of plant he raises and try to make the conditions such as will best suit each kind of plant or crop.

Soil that is well filled with roots is not subject to erosion as is barren soil. Use is made of this fact in planting certain grasses for their binding effect, especially on the coast where the constant washing of the waves has a tendency to change the coast line.

The roots of leguminous plants become infested with certain bacteria found in the soil. These bacteria form bunches or nodules on the roots in which they live. Thus protected, they gather nitrogen from the air, use what they need, and store up the rest. This surplus is used by leguminous plants in making protein, part of which is found in the body of the plant, and part in the seeds. When the seeds are used as food, man and the animals secure the protein which they need. When the plants die, they leave the soil richer in nitrogen in a form that can be used by plants which do not have the help of the bacteria to gather it. So valuable is this form of fertilizer, that in some cases,

leguminous crops are raised and plowed under for the sake of the nitrogen in them, this being called "green manuring," a practice which was carried on for a long time before the reason for its value was learned.

FIGURE 246. — EFFECT OF INOCULATION ON GARDEN PEAS. No. 1, uninoculated. No. 2, inoculated.

The relation which exists between the plants which profit by the work of the nitrogen-gathering bacteria and at the same time furnish them protection is an illustration of *symbiosis* (sym-bī-ō′sis: Greek, *sym*, together; *bios*, life),

FIGURE 247. — EFFECT OF BACTERIA ON THE GROWTH OF RED CLOVER IN A POOR SAND.
Left, uninoculated; right, inoculated.

the relation of mutual helpfulness between organisms of different kinds.

223. Inoculation. — Nitrogen-gathering bacteria are likely to be present in all soils in small numbers, but in order to

have them help plants to an appreciable degree, there must be many of them. It has been found possible to place them in the soil artificially, a process called inoculation. This is done either by wetting the seeds with water containing the bacteria, or by putting them into the soil in some other manner. Care should be taken to secure only pure cultures (see page 313) and to have them fresh. By the use of cultures a soil properly inoculated will not only produce larger crops of leguminous plants, but its quality is also improved for crops which follow them, as explained above.

SUMMARY

The root is the part of the plant that grows in the soil to gather water and food materials for it, to hold it securely, and to store food for it. Roots have many forms, the primary or tap root and the fibrous roots being the extremes. Small roots have a root cap to prevent injury to their tips, and root hairs to increase their absorbing surface. There are specialized roots for special purposes, such as aërial roots for support and for gathering water. Adventitious roots are those that grow on "slips." Roots form an important part of man's food, and food for his animals.

QUESTIONS

What is the root? What does it do for the plant? Describe the structure of a tap root. How do fibrous roots differ from a tap root? In which kind of roots is most food stored? What use does the plant make of this stored food? What use does man make? What kinds of food are stored in roots?

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Bergen and Caldwell, Practical Botany, pages 5–16, 24–38.
Conn, Biology, page 112.

CHAPTER XIX

STEMS

224. Definition. — The stem is that part of the plant which forms the connection between the roots and the leaves. It is adapted to its work (1) in being compact and sturdy, enabling it to bear weight; (2) in branching, to afford a larger number of points for the attachment of leaves; (3) (in some cases) in being provided with thorns or briers, as in the blackberry and rose, to protect it from being injured by animals; (4) in being covered with a strong epidermis or, in woody stems, with bark which protects it from outside injury and keeps it from drying up; (5) in plants which grow in the water, in having large air spaces to carry air to the roots which lie in the mud at the bottom of the water.

An underground stem can always be distinguished from a root by the buds of new leaves or the scales of old ones, although in some the leaves are reduced to mere scales, as in the potato. Underground stems usually send up aërial shoots. They often have an advantage over an aërial stem in being better protected. Some plants make use of the underground stem in propagating themselves (see page 305).

225. Position of Stems. — Stems assume a variety of positions, but that which serves the purpose of most plants best is the upright, independent position. Any tree illustrates this kind of stem. A few which are upright keep that position by twining or by clinging to an upright support, which may be some other plant. These plants have comparatively weak stems. Creeping or trailing stems lie on the ground with only the tip erect. This position is illus-

trated by the habit of the ground pine and by the running blackberry. A creeping stem may lie beneath the surface of the ground, as in the case of the Canada thistle or the "quack" grass. (See also Figure 305, Pteris, and Figure 311, Club Moss.)

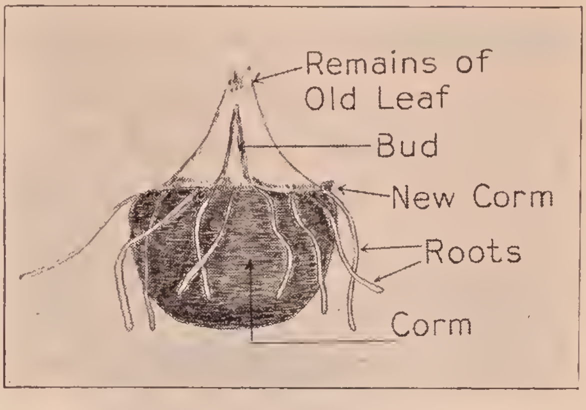

FIGURE 248. — INDIAN TURNIP.

226. The Duration of Stems. — The length of life of a stem depends upon its habit in producing seeds. An annual or herbaceous stem, like the morning-glory or the lady-slipper, dies at the end of the first season, the plant having produced its seeds. Other stems, like the trees, last year after year. Some of the redwood trees in California are known to be more than three thousand years old, and the Cedar of Lebanon, growing in Asia Minor, is known to live as long.

227. Uses of the Stem to the Plant. — The stem is of use to the plant in being the place for the attachment of leaves, and in providing a path for the vessels which carry water from the roots where it is gathered to the leaves where most of it is used. A third use of stems is for the storage of food, as in the potato. A few plants make use of stems for propagation, as in the case of the strawberry and the raspberry (see page 271).

FIGURE 249. — STARCH GRAINS HIGHLY MAGNIFIED, SHOWING LINES OF GROWTH.

228. Uses of the Stem to Man. — Man makes use of the stem for food, the potato being one of the most familiar examples as well as a common source of food. Starch is also made from potatoes. The stem and buds of asparagus are used for food.

A second use is for shelter. Trees furnish lumber in all

its varieties. Some parts of houses can be made from stone, brick, or other materials, but for the inside finishing we are still dependent upon wood.

A third use is for furniture. No other material has been found that is so satisfactory as wood for tables and chairs.

A fourth use is for clothing. The flax plant which furnishes the material from which linen is made is one of the most valuable. Its usefulness depends upon the bast fibers which it contains. These are found in the outer part of the slender stem and serve to give it stiffness. When separated from the other parts of the stem they can be twisted, spun, and woven.

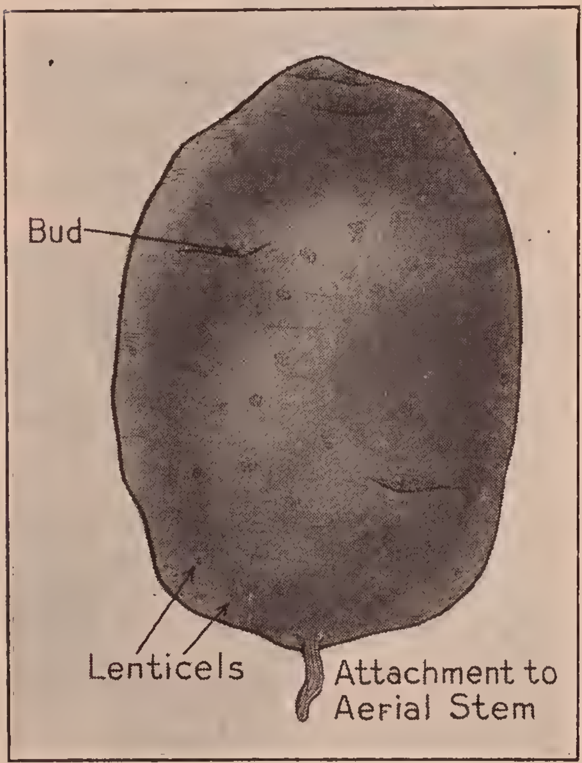

FIGURE 250. — POTATO, SOMETIMES CALLED A TUBER.

A form of underground stem used for storing food.

A fifth use is for cordage. This includes all kinds of ropes and many kinds of strings. Some cordage is obtained from fibers of hemp, and some from other plants.

Among the many other uses of stems in our daily life may be mentioned poles for telegraph, telephone, and electric light wires, for the masts of ships, for the piles of piers, timbers for props of mines, lumber for bridge foundations, cross-ties of railroads, besides parts of implements and tools of daily use, vehicles and parts of machines by which many of these are made. Add to these the boxes, barrels, crates, trunks, pails, baskets, and other common articles which we use frequently, and paper in its many forms and numerous uses. It is evident from this list, which is far from complete, that man has found the

stems of plants to be of great use to him, and that he could not well do without them.

229. Adaptations of Wood. — When we compare the number of articles that are made of wood with the same articles made of substitutes, we see that there are some good reasons for the use of wood. Among these are its *lightness* compared with iron or steel for use in furniture, trunks, and other articles, its *elasticity*, its *toughness*, its *durability*, especially when protected from dampness, the *ease* with which it can be shaped by tools, and its *beauty*, depending on color and grain, and on the high polish it can take.

230. Specialized Stems. — In regions where the climate is very hot and dry most of the year, the leaf surface is greatly reduced to prevent undue evaporation. In this case the stem becomes green and performs the work of photosynthesis (see page 278), ordinarily done by leaves. The cactus illustrates this. Certain other plants have no leaves but the stem branches in such a way as to resemble leaves. The florist's smilax and asparagus fern represent this kind of branching. The true leaves are reduced to minute scales.

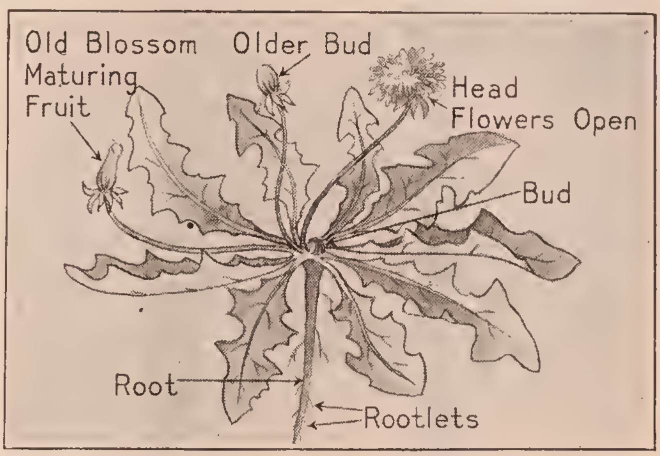

FIGURE 251. — "STEMLESS" PLANT — DANDELION.

LABORATORY STUDY OF STEMS

Draw a potato. Label the "eyes" *buds*. On which end are they more numerous? Label *scale*, just above *bud*. Note end where it was attached to the main plant.

Cut off the stem end and stand in water colored with red ink. After two hours examine again and note what part is stained. Cut off slices till traces of color disappear. Draw to show where it is colored. Cut a thin slice and put a few drops of weak iodine on it. What happens? What does it show?

Cut an onion vertically. Note the condensed stem on which the leaves are arranged.

Draw a twig of horse-chestnut in winter condition. Label *rings* (scars of scales), *terminal bud* (on end), *lateral buds* (on sides), *leaf scar* (oval mark below bud), *vascular bundles* (on leaf scar). How many? How are the lateral buds arranged? Remove the scales carefully. Count and draw them. Describe them. What do you find inside? Draw and describe.

FIGURE 252. — STEM OF HORSE-CHESTNUT.

A, a season's growth; *B*, terminal bud; *C*, lateral bud; *D*, leaf scars; *E*, fibro-vascular bundles; *F*, rings caused by scales of last year's terminal bud.

Compare with twigs of other trees — hickory, elm, maple, basswood. What differences do you notice?

231. External Appearance of Woody Stems. — If we take for an example a twig of the horse-chestnut, we shall find on the outside a brownish bark, some scars showing the position of last year's leaves, and some rings extending around the twig, indicating where the scales were attached that covered the bud containing these leaves. Above this scar will be found a bud covered with sticky scales and at the end of the twig a large terminal bud. The buds which grow above the leaves are called axillary buds. If more than one of these is found in an axil the additional ones are called accessory buds. The strength of the terminal bud determines the kind of branching of a trunk. A single very strong

terminal bud gives the *excurrent* (Latin, *ex*, out; *curro*, to run) trunk of the evergreen trees, and a number of terminal buds of equal strength give the *deliquescent* (Latin, *de*, from; *liquescere*, to become liquid) branching of the elm and other trees. Between these extremes there are many intermediate forms. The buds for next season's leaves are formed very soon after the leaves have reached their full size in the spring. Buds are protected in winter by coverings of scales which prevent them from becoming dry. A bud may contain leaves only, or flowers only, or both. Small markings on the smooth bark are lenticels, spots where the outer layer of the branch is broken, allowing air to enter the inner portions.

FIGURE 253. — ELMS.

Note the lack of a strong central stem and the repeated dividing of the branches, illustrating the deliquescent stem.

232. Growth of Stems. — Most woody plants grow rapidly in the spring and early part of summer, after which they cease increasing in size but continue to add material which makes wood, thus enabling the stems to resist killing in the winter. Such plants are said to have a *definite annual growth.* This is illustrated by most woody trees. Other plants continue to grow until the end of the season. The latest formed wood in such plants is usually killed by the frost, with the buds on it. The plant begins to grow next season from axillary buds below the point where it was killed. Such plants are said to have *indefinite annual growth.* Examples are red raspberry and sumac. Advantages of definite annual growth are twofold: (1) it enables a tree to grow very rapidly in the spring when conditions are most favorable

for growth, and (2) it does not result in the loss of any wood once formed. On the other hand, the plant which makes an indefinite annual growth can take advantage of favorable growing conditions whenever they occur, although it may lose some of its youngest wood if frost comes before it is hard enough to resist it.

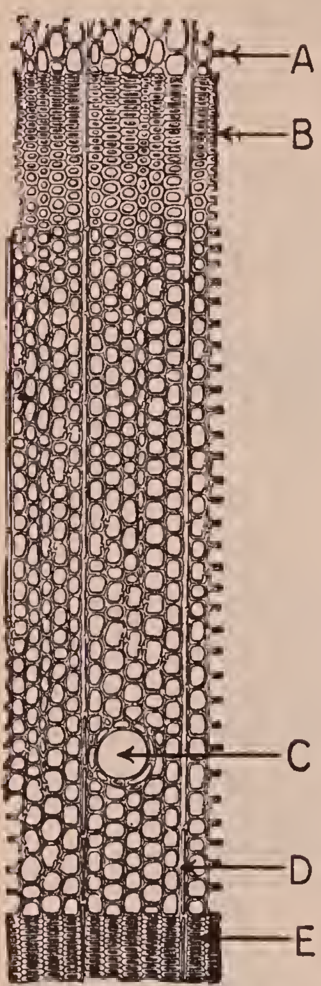

Figure 254. — Wood of Spruce, Greatly Magnified.

A, large cells formed early in season; *B*, *E*, small cells formed late in season; *C*, resin duct; *D*, medullary ray.

In the annual growth of woody stems, a new node is added to each branch, and a new layer of wood over the wood of previous years. This makes it possible to tell approximately how many years old a tree is, the growth of each year forming a ring more or less distinct according to conditions. When the conditions for growth are at their best, the cells formed are large. As conditions become less favorable, the cells become smaller and have thicker walls, marking distinctly the end of one season's growth from the beginning of the next. The size of the cells varies greatly in different trees, producing the "grains" which are so characteristic of each kind of lumber.

233. Vascular Bundles or Fibro-vascular Bundles. — Vascular bundles are a part of the conductive system of the plant. They are in stem, root, and leaves. In the leaves we call them veins. In celery they are the "strings" (see Figure 256).

234. Structure of a Vascular Bundle. — A vascular bundle in a monocotyledonous plant is made up of two kinds of cells or groups of cells called *xylem* (zy′lĕm) and *phloem* (flō′ĕm). The xylem cells are thick-walled, but with thin spots in each cell where it touches another cell of the same kind. Each

cell is long and pointed. Some of these cells overlap in such a way that they make continuous tubes from the root, up through the stem, and into the leaves. The thick walls help to give firmness to the plant.

The phloem cells are the other part of the vascular bundle in a monocotyledonous stem. They have thinner walls than the xylem cells and they communicate with one another through the ends and not through the sides. The ends of these cells have perforated plates through which the liquid in the cells passes. These are called *sieve plates.*

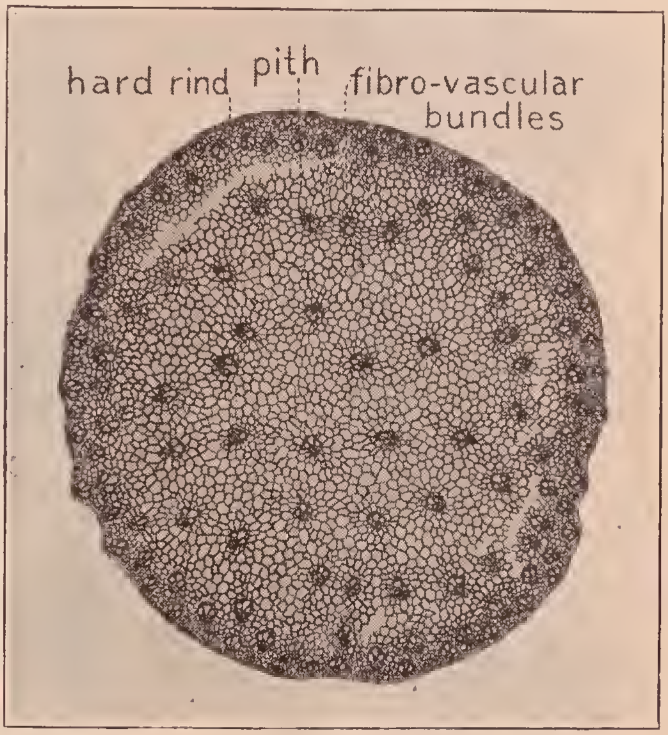

FIGURE 255. — CROSS SECTION OF CORN STEM.

Note the fibro-vascular bundles scattered throughout the pith.

In a dicotyledonous stem, the vascular bundles are made up of three kinds of elements, the *phloem,* like that of the monocotyledonous stem, and the *xylem,* also like that already described. Between them is a layer of thin-walled, brick-shaped cells called *cambium* where growth is taking place rapidly. This is the cambium or *meristem* tissue. The side towards the phloem is constantly producing phloem cells, and the other side xylem cells. Associated with the phloem cells are bast fibers, the function of which is to give strength and firmness to the stem.

235. Arrangement of the Vascular Bundles. — This differs in the two kinds of stems already mentioned. In the corn stalk, a monocotyledonous stem, the vascular bundles are scattered throughout the central pith, and the bundles have no definite

position with reference to the center. The outside of the stem is covered with a hard rind which often contains silica, a substance like glass which makes it hard and strong. In grasses, the stem is hollow, and the bundles are of course around the edges, some of them passing off at each node into the leaf which arises from it.

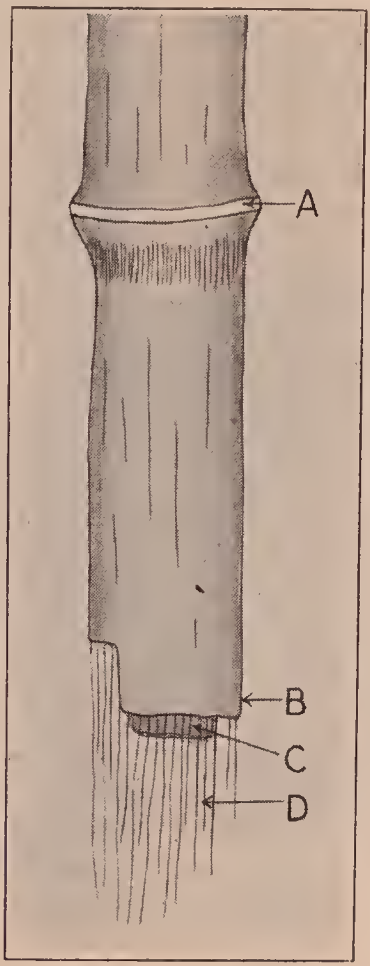

FIGURE 256. — CORN STEM, BROKEN.

A, node; B, hard outer rind; *C*, pith; *D*, fibro-vascular bundles.

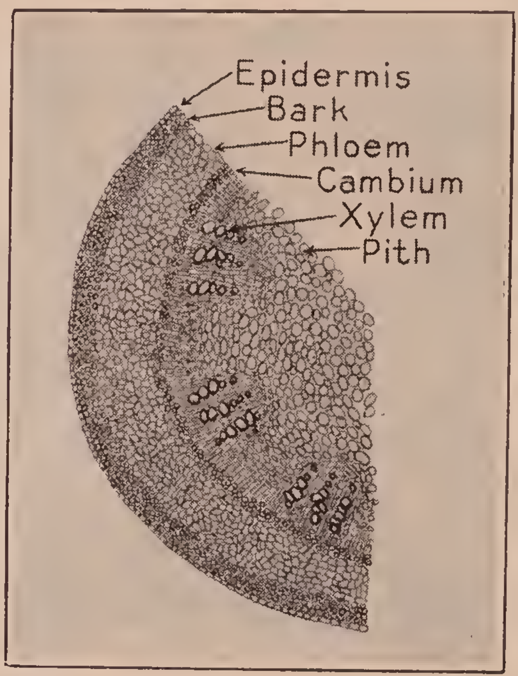

FIGURE 257. — PART OF CROSS SECTION OF YOUNG DICOTYLEDONOUS STEM.

Note the arrangement of the fibro-vascular bundles. These gradually form a complete ring. The cambium layer in an older stem lies under the bark. Its color is green.

236. The Work of the Vascular Bundle. — We have said that the vascular bundles are a part of the conductive system of a plant, and that some of the cells form vessels. There is little likeness to the vascular system of animals, however, for the system in plants lacks an organ for driving the liquid in the tubes, and it has little use as an aid to respiration. Water,

absorbed from the soil by the root hairs, is passed by osmosis to the slender cells in the roots, and from there *up* through the stem and to the leaves, where it is used in photosynthesis. After the food made by photosynthesis is digested and thereby made ready for the use of the plant, some of it is carried *down* through the phloem part of the vascular bundle to such parts of the plant as need it. There is in this a likeness to the circulation of animals in which fresh blood is carried in one set of vessels and blood that needs renewing in another set. The liquid which is carried in the vessels of plants is commonly called sap, and when a plant is broken, and the sap exudes, we speak of it as bleeding.

HOME WORK — STEMS

1. Examine the house you live in to learn, if possible, the kinds of lumber used for the floors, for the casings, and for the doors. What kinds do you like best? Why?

2. Examine all the wooden furniture and answer the same questions.

3. Examine the different kinds of matting. Of what is each made? Examine linoleum. Of what is it made?

4. Examine the wicker furniture. Of what is it made? What is rattan? Bamboo?

5. Examine your "straw" hat. Of what is it made? How?

6. Examine the doormat. Was it made from any part of the stem of a plant?

7. Examine the clothes-basket and the market-basket, and the sewing-basket, and try to decide from what each was made.

8. Examine a trunk, a box, a barrel, a pail, a picture-frame, a harness, a wagon, an automobile, a fence, telegraph poles, paving blocks, corks, and toys of various kinds, to find what parts of them are made from wood, and what kinds of wood are used.

9. Make a list of all the other things, as spools, that are made of wood.

10. What substitutes for wood do you find? In what respects are they better? in what respects inferior to wood?

11. How is paper made?

12. What is celluloid?

13. Where is thatch used?

14. What is oakum? In what industry is it used?
15. Why is excelsior a good material for packing fragile articles?
16. Into which of your garments does linen enter?
17. What is jute? manila? burlap?
18. How many trees do you know? Which do you like best? Why?

PRACTICAL APPLICATIONS — STEMS AS A MEANS OF PROPAGATING PLANTS

"Slipping" plants is a common practice, the success of which is due to the fact that adventitious roots grow readily from the cut end of a branch of geranium, balsam, ivy, and other plants. Two advantages make slipping popular: (1) the certainty of securing a new plant like the parent plant, (2) the short time required to produce blooms compared with the same kind of plant raised from the seed. Willow twigs root so readily that it is often possible to start a hedge by sticking pieces of branches into the ground when it is very wet.

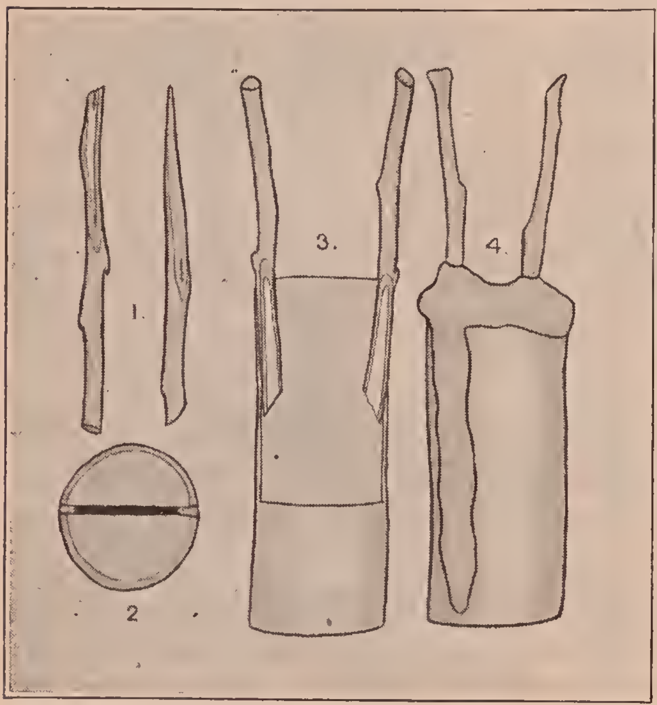

FIGURE 258. — CLEFT GRAFTING.

In 1, the twigs or scions have been cut obliquely to expose the cambium. In 2, a branch of the stock has been split to receive the scions. In 3, the scions have been inserted into the stock, cambium against cambium. (The outer part of the branch is represented as having been removed.) In 4, the wax has been applied.

Grafting is a common method of propagating trees. It depends for success upon putting the cambium layer of a twig from one plant against the cambium of another and fastening it there until the two layers have grown together, protecting it from moisture, insects, and

fungi by a layer of wax. Usually a twig from a mature tree (the scion) is grafted upon the young stem of a seedling or on an inferior tree (the stock), producing fruit several years earlier than the seedling tree would. One can be sure, too, of obtaining the fruit wanted. If twigs from several kinds of trees be grafted upon a "scrub" tree, each twig will bear its own kind of fruit. At the same time the quality of the fruit on the tree's own branches will be greatly improved. The pome fruits, drupe fruits, and citrus fruits are usually grafted. Greenhouse roses, azaleas, and other plants are propagated in this way. Budding is a process similar to grafting except that a bud is slipped into an incision in the bark, instead of a twig being inserted into the end of a branch.

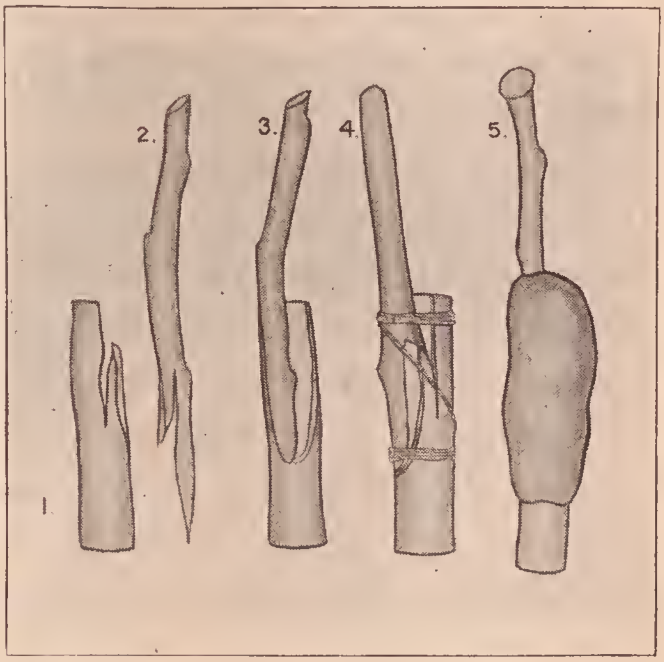

FIGURE 259. — WHIP OR TONGUE GRAFTING.

In 1, the branch has been cut to expose cambium in two places. In 2, the scion has been cut to fit the branch. In 3, the scion has been laid in place. In 4, the scion has been tied to the stock. In 5, the wax has been applied.

Layering is a method of obtaining new plants by covering a branch with earth some distance from its tip. When roots form, the branch is severed from the main plant and transplanted. Roses, grapes, and currants are propagated by layering. All these methods are artificial, and seldom found in nature.

Other plants propagate themselves by stems naturally, as the strawberry, which puts out long, leafless branches called stolons or runners, each stolon having a bud on the end which takes root when it finds favorable conditions, especially contact with the soil. When a new plant is well established

the stolon ceases to carry nourishment from the parent plant and soon dies. Black raspberries produce long, drooping stems which have buds on the ends similar to those on the stolons of strawberries. New plants are formed when these rest on the earth, several sometimes arising from the branching end of a parent plant, from which it later becomes separated.

A large garden lily has a method of propagating itself that is not common, namely by bulblike growths produced in the axils of the leaves.

Canada thistles, quack grass, and devil's paint-brush are among the most difficult of weeds to eradicate owing to their branching, underground stems, each piece of which, when broken off by cultivation, forming a new plant. Dandelions, because of their greatly reduced stems, are not easily killed by trampling. In digging dandelions from lawns, care must be taken to cut deeply enough to remove the whole crown of the plant, otherwise the injured stem branches and forms a weed more troublesome than the original one.

SUMMARY

The stem is the part of the plant which forms the connection between the roots which gather food materials and the leaves, where food is manufactured. It is compact and sturdy because it must bear the weight of the leaves and branches, and because the vessels through which liquids are conducted in it must be well protected. Most stems grow above ground and upright, but some lie on the surface of the ground, and some below the soil. The stem of the woody plants is employed by man in more ways than any other part, furnishing him shelter, fuel, furniture, clothing, paper, parts of many machines and implements on which he is daily dependent. Stems are a source of some food for man and the stems of the grasses furnish food for many animals.

QUESTIONS

What is the stem? What is its use to the plant? What positions do stems take? How long do they live? Name and describe the peculiar stems. What are vascular bundles? How are they arranged in a monocotyledonous stem? in a dicotyledonous stem? What is their work? What is meant by definite annual growth? indefinite annual growth? What are annual rings? How are they formed?

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Bergen, Foundations of Botany, pages 62–129.
Bergen and Caldwell, Practical Botany, pages 11–13, 39–103.
Coulter, Plant Life and Plant Uses, pages 49 and 143–193.
Gibson, Sharp Eyes, pages 48–51, 240–243.
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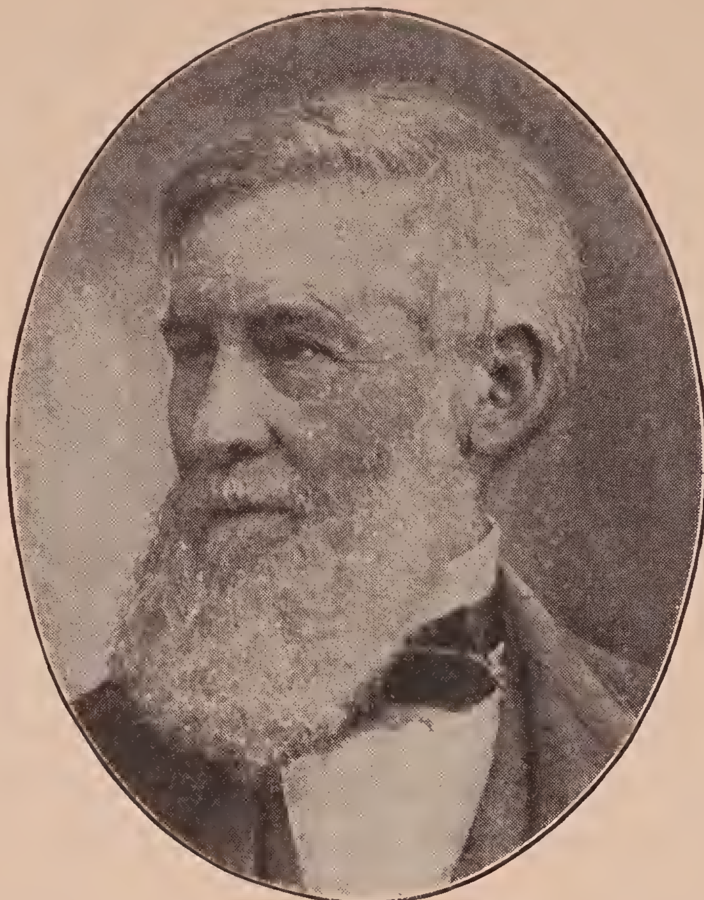
CHAPTER XX

THE LEAF

The leaf is the most important organ of the plant, for in it are carried on most of those processes which pertain to the life of the plant itself. Because it is so important an organ and because it has so many kinds of work to do, it has many adaptations in form, position, and structure which fit it to do its various kinds of work, besides giving individuality to plants. We shall study the work of the leaves first in order that we may more easily understand how the structure, form, and position of the various kinds of leaves adapt each to its work.

237. The Work of a Leaf. — The life processes carried on by the leaf are (1) *photosynthesis*, peculiar to plants having chlorophyll, green coloring matter; (2) *respiration*, common to all living protoplasm; (3) *digestion*, (4) *circulation*, (5) *assimilation*, and (6) *excretion*. All but the first are much the same as the processes of the same names in animals. *Transpiration* which, like photosynthesis, is peculiar to green plants, while not one of the life processes, is made necessary by them.

The work that a leaf does is of greater importance than anything else about it. We study its structure in order to understand how it is able to carry it on. For the same reason we study the arrangement of the leaves on the stem, and their form, which has a close relation to arrangement Although the work that leaves do for plants is the same in all kinds of plants the world over (with a few exceptions to be noted later), each particular kind of plant has its peculiar shape, size, and arrangement of leaves. This helps us to



Asa Gray (1810–1888) was born at Paris, Oneida Co., N. Y. He started out in life to be a doctor and took the degree of M. D. in 1831, but his main interest was in botany. Deserting the practice of medicine, he took up his favorite study which was to make him the most famous American botanist of his time.

After studying plants for a number of years, he became professor of natural history at Harvard, to which university he gave his remarkable collection of plants.

Professor Gray was able to present technical facts in an interesting and simple manner. This helped to give a wide use to his numerous, scholarly textbooks on botany. His contributions to the science of botany were very important and gained for him international recognition.

He never took a real course in botany but made plants his teachers.

(Photograph used by courtesy of Harper and Brothers.)

distinguish one kind of plant from another and to describe and classify them. We need to know the meaning of certain terms used in describing leaves in order to read or to talk about them intelligently, so we must be familiar with those most commonly known. These can soon be learned by referring to the figures and explanations.

In many ways, flowering plants are more intricate organisms than animals. Without the ability to change their environment, they must depend upon the soil as they find it, rich or poor, wet or dry, soft or hard, to furnish them water and such food materials as come to them in liquid form. Without being able to seek shelter, they must take sun or shade, heat or cold, rainy weather or dry, pure or impure air just as each comes. Lacking organs of offense or defense against other plants they must contend with them for moisture, air, and light, besides being subject to the attacks of organisms which injure them. In addition to making of themselves the best plants possible under the conditions, they must produce numerous offspring, furnish each new plant with a supply of food, and send them all out into the world to meet and to make use of such conditions as they may find. An examination of the plants in any garden or yard will show that varying degrees of success have been attained. In every case, however, it represents the best that could be done under the circumstances. When we consider that plants have not intelligence such as animals possess, it appears all the more remarkable that they can accomplish so much, often under very adverse conditions. The biologist's great interest in plants is in the ways they adapt themselves to carry on their life processes under all sorts of conditions, as well as in the processes themselves. Those who raise plants can expect success only as they are able to supply the conditions under which each plant thrives best, and to control conditions and organisms which may be unfavorable.

A study of its leaves shows how a plant solves many of its problems.

238. Parts of a Leaf. — The main part of a leaf is the *blade.* The petiole (Latin, *petiolus,* fruit stalk) is the part by which it is attached to the twig. This sometimes has small projections called *stipules* at the base.

239. Venation. — The leaf of most plants contains ribs or veins which determine its main form and serve to keep it firm.

FIGURE 260. — SKELETON OF POPLAR LEAF.

Note the epidermis still remaining on part of the leaf. Poplar leaves skeletonize very easily. This was picked up on the street.

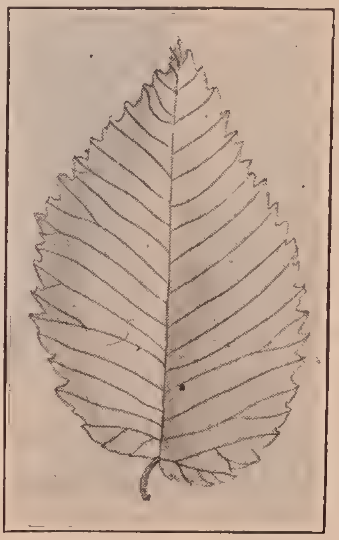


FIGURE 261. — LEAF OF ELM.

Simple leaf with a serrate margin and pinnately-netted venation. Note that the leaf is asymmetrical at the base. The general shape is ovate oblong, with a sharp apex.

There are two main types of arrangement of veins. The first, that in which there are a few veins of about the same size which run side by side without branching from the base of the leaf to the tip. These are the parallel-veined leaves found in grasses, lilies, and most other monocotyledonous plants. In the second type, the netted-veined leaves, a few main veins branch and divide, filling the spaces between them with a

fine network of small veins. The main veins may have a palmate arrangement, as in the palmately-netted vein of the maple, or they may branch from a central vein, as in the pinnately-netted-veined leaf of the elm. In such a leaf, each branch of the mid-vein usually ends in a point of the margin, or in a notch.

240. Forms of Leaves. — A leaf is said to be *simple* when the blade is all in one part, and *compound* when it is divided

FIGURE 262. — PALMATELY COMPOUND LEAF OF WOODBINE.

into three or more leaflets. The apple and the maple have simple leaves, the clover and the horse-chestnut have compound leaves. A compound leaf is *pinnately compound* when its leaflets branch from the midrib, as in the rose or the locust; *ternately compound* when there are three leaflets, as in the clover and oxalis, and *palmately compound* when there are five or more leaflets, as in the horse-chestnut and woodbine. Besides these general terms, the shape of the base of a leaf, the general shape of its blade, its tip, and its margin all have descriptive names which help us to

recognize any combination of them as belonging to a particular leaf. For instance, the apple leaf is ovate-oblong, rounded or cordate at the base, with a serrate margin. A leaf with a blade as large as the combined surfaces of a compound leaf would be much more easily torn by the wind, and would cut off more light from the leaves below. Some leaves are very finely divided, being many times compound, like the carrot and the yarrow.

PHOTOSYNTHESIS

241. Definition of Photosynthesis. — The word photosynthesis (Greek, *phos*, light; *synthesis*, composition) means putting together by means of light. It is the process of manufacturing carbohydrates from raw materials, a vital process performed only by green plants.

242. The Process. — Many facts about this process are not well understood, but we can state a few with certainty: (1) that in the manufacture of carbohydrates by photosynthesis, carbon dioxide is used as one of the raw materials, the source of this gas being the air, in which it exists 3 or 4 parts in 10,000, and the waste of the plant's own respiration; (2) that another raw material used is water, which is taken up by roots; (3) that some oxygen is left over as a by-product and given off as a waste of the process of photosynthesis; (4) that chlorophyll, the green coloring matter of plants, is essential; (5) that light is necessary not only to develop the chlorophyll but also to enable it to manufacture carbohydrates; (6) that another necessary factor is a moderate degree of warmth.

243. The Products. — Carbohydrates are the first visible product of photosynthesis, but proteins and oils result from later processes, probably very similar to photosynthesis, which take place in the green leaf.

244. The Use Made of the Products. — The carbohydrates, proteins, and oils thus made are used in three ways:

(1) some of it is digested in leaves and built up into new protoplasm; (2) some of it is stored in the leaves to be used later; (3) another portion is stored in other parts of the plant, as in the potato, in seeds, buds, and roots.

Comparison. — The process of photosynthesis may be compared to any other manufacturing process which requires:

1. A factory — in this case, green leaves.
2. Machinery — the plant cells containing chlorophyll.
3. Power — light from the sun, a form of energy.
4. Raw materials — carbon dioxide and water, and small portions of nitrogen and other chemical substances which are dissolved in the water taken in by the roots.
5. Working hours — daylight.

In this comparison the *products* are the carbohydrates and other forms of food which are made from them, and the *by-product*, oxygen. This manufacturing process disposes of its products (1) by storing them on the premises, the leaf; (2) by using them on the premises, digesting them to make more protoplasm; (3) by sending them away to other parts for storage, or immediate use; (4) by using them to make other food substances, namely, proteins, and fats or oils.

245. The Importance of Photosynthesis. — The importance of photosynthesis cannot be overestimated. It is the only natural process in the world by which raw material can be changed into food and by which energy can be stored up for future use. The plant makes use of this stored-up energy to produce new leaves, flowers, etc. Animals, which have not the ability to manufacture food from raw materials, depend directly or indirectly upon green plants for their supply of food. Besides making all the vegetable food in the world, plants, in using the carbon dioxide produced by animals, keep the air free from excess of it and so make it safe for animals to breathe. They also, by the same process, keep it well supplied with oxygen. Photosynthesis is

the most important work of the leaf, as well as the vital process on which all other vital processes, both in plants and animals, depend.

A second function of the leaf is to perform respiration. Respiration in plants is exactly the same as respiration in animals. That is, every living cell uses oxygen, combining it with some of its protoplasm, releasing energy for the work of the plant and forming carbon dioxide and other wastes in the process. Respiration is most easily studied in plants like toadstools which cannot perform photosynthesis, and in sprouting seedlings which have not developed chlorophyll.

HOME WORK ON PHOTOSYNTHESIS

Make a list of the plants that are used for food. Look up in an encyclopedia the amounts of each produced in a given year. Make a list of the industries which are dependent on agriculture. Obtain information concerning the number of men employed in each.

What uses are made of starch and sugar aside from food?

What are the sources of the protein used for food? Which of these depend directly upon photosynthesis? which indirectly upon it?

LABORATORY STUDY

To show that light is necessary for photosynthesis, fasten thin discs of cork to the upper and under sides of a leaf with clips, completely shutting off the light. Stand the plant in the bright light for half a day, then remove the corks from the leaf and the leaf from the plant. Heat enough 60 per cent alcohol to cover the leaf in a shallow glass dish. This may be done by setting the dish into hot water. Keep hot for half an hour, or till the chlorophyll is removed from the leaf. Turn off the alcohol and put drops of weak iodine on the leaf. Note that the circle covered by the cork discs show little starch or none, as indicated by the faint blue color or by lack of color.

Make a similar test by comparing a leaf from a plant that has been in the dark twelve hours with one that has stood in the bright light for the same time, using alcohol to remove the chlorophyll and iodine for a test for the presence of starch, as before.

To test the nature of the gas given off by growing algæ collect a quantity of algæ and place it in a deep glass jar in the sunlight. When

bubbles begin to show, place an inverted funnel over the algæ. Fill a test tube with water and invert it over the upright stem of the funnel. When an inch or more of the gas has collected in the test tube, remove it carefully and thrust a glowing splinter into it. Increased brightness of the glow or bursting into flame shows that oxygen is present.

246. Digestion of Food. — Although the plant manufactures food from raw materials, it cannot make use of it until it has been digested. The process of digestion takes place chiefly in the leaf and the digested food is carried to all parts of the plant which need it through the vascular bundles. There are many facts about digestion in plants which are not so well understood as this same process in animals. It is known, however, that the enzyme, *diastase,* which digests starch, is secreted by the protoplasm of the cells and that it is very similar to ptyalin, the ferment in the saliva of animals which digests starch.

247. Circulation. — Circulation in plants differs from circulation in animals in not having any central organ for keeping the fluids in motion and in the substances which the vessels contain. The xylem of a vascular bundle (Figure 255) carries water taken up by the roots from the soil to the leaves, where it is combined with carbon from the air and built up into foods. The digested foods are carried from the leaf to the parts of the plant which need them in the phloem part of the vascular bundle, so that, generally speaking, we have an ascending stream of water in one part of the bundle and a descending stream of digested food in the other part. The term *sap* is used to include both. Sap is moved by the combined influence of osmosis (root pressure), transpiration, and possibly other factors.

248. Assimilation. — This is the actual taking up by the plant cells of such parts of the digested food as they need. It is a building-up process which results in the growth of the plant till it reaches the stage of maturity and in maintaining it at that size.

249. Excretion. — Excretion in plants is the same as in animals in this respect that it is getting rid of material or substances which are no longer of use to the plant. It very often happens, however, that these are not removed from the plant as in the case of animals, but are simply stored where they can do no harm. An example of this is the crystals of calcium oxalate which give to sorrel, or sour grass, its sour taste. The line between excretion and the secretion of certain substances, such as the oils in peppermint plants, is not easily drawn. In the case of the secretions, however, they often serve the purpose of preventing animals from eating the plants.

250. Transpiration. — This is the process of evaporation which takes place in plants, water in the form of vapor escaping through very small openings in the leaves called stomata. It is not one of the vital processes but closely connected with them. Its only similarity to perspiration in animals, to which it has sometimes been likened, is that water is given off through openings in the outer covering of the plant. Transpiration is unavoidable because the roots of a plant usually take up more water than is needed for the vital processes, and because this excess accumulates in spaces which communicate with the outside through the stomata. The function of the stomata is to allow air containing nitrogen to pass into the leaf, and excess oxygen to pass out. Incidentally, however, water passes out too. When transpiration is too rapid, the plant is deprived of needed water. Since transpiration is a menace to the well-being of a plant, numerous devices have been developed for regulating it. Thus: 1. The surface of a leaf is covered above and below by a layer of *cutin*, a transparent substance impervious to water, perforated only where stomata occur.

2. The stomata are on the under side of the leaves in most plants, this position being less favorable to transpiration than the upper side.

3. The stomata contain guard cells which regulate the size of the opening by absorbing moisture or losing it. When the guard cells are full of water, they are plump or *turgid*, leaving the stoma wide open. When they are soft or *flaccid* from lack of water, they collapse, partially closing the stoma.

4. In addition to this regulating device the stomata may be under coverings of hair or wax to make evaporation less rapid, or they may be at the bottom of a very thick layer of cutin.

5. A leaf may still further check transpiration by changing its position or by rolling its edges together. Corn leaves during a very dry period illustrate this.

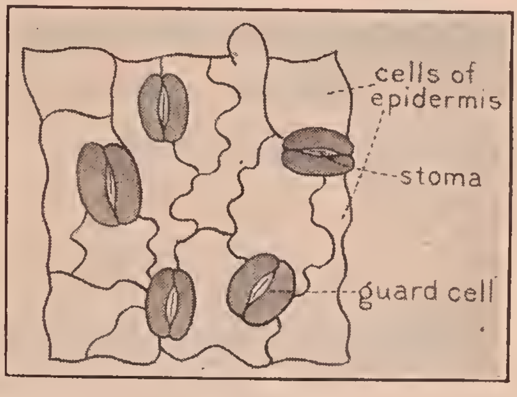


FIGURE 263. — BIT OF EPIDERMIS OF LEAF.

The dark structures are stomata. An area as large as a period on this page contains hundreds of stomata.

6. Another device is seen in cactus plants which have a greatly reduced surface. The stem in these plants is green and it contains stomata, thus enabling it to do the work of leaves.

7. The shedding of leaves in the fall is a device used by *deciduous* (dē-sĭd′ū-ŭs: Latin, *deciduus*, falling off) trees to prevent undue transpiration. When the ground is frozen the roots are unable to absorb much water. If the leaves remained on the tree, water would be given off more rapidly than it could be gathered from the soil, resulting in damage to the plant.

When the moisture in the air exceeds a certain quantity, evaporation does not take place readily, causing too much water to accumulate in the plant. To prevent damage from this condition, plants have modified stomata, called water pores, at the ends of the veins. These contain cells

which burst under pressure, allowing the water to exude. This process is known as guttation, and the drops so formed, as guttation drops. These are often seen in the morning on the ends of grass blades, and on the points of leaves that have serrate margins, like the strawberry. Guttation drops are sometimes absorbed by the plant and sometimes they evaporate, depending on the needs of the plant and the amount of moisture in the air, or, as we say, the *degree of humidity*.

The amount of water that leaves a plant in a day by transpiration alone is very great. For example, a moderate-sized sunflower plant will give off a quart a day under ordinary conditions.

LABORATORY WORK ON TRANSPIRATION

Turn the under side of a geranium leaf or other large leaf so it lies against a cool window pane, holding it there in some way if necessary. After half an hour remove it and note the drops of moisture which resulted from transpiration. Try other leaves in the same way. Fasten a watch crystal to the *under side* of a leaf, using clips to hold it and vaseline to make the edges air tight. Do the same with the *upper* side of another leaf. Which side gives off moisture as shown by drops on the watch crystal? Plunge a large leaf into water and set in the sun. On which side do bubbles appear? Wait half an hour. What kind of gas do they contain? What process in the leaf produced them? If you cannot answer this now, try again after reviewing photosynthesis.

Take three leaves from the same plant. Coat one on both sides with paraffine or vaseline, one on the upper side only and one on the lower side only. Lay them aside till your next laboratory period. Describe all three. Which is least wilted? Why? Lay them all aside till all are wilted, observing them now and then and making a record of what happens.

Hold a leaf up to the light and notice the arrangement of the veins and the soft parts.

Thoroughly water a fern or other plant growing in a jar. Cover the earth with tinfoil, oilcloth, or paraffine to prevent evaporation from the surface. Weigh it carefully, then let it stand on the scales,

adding weights from time to time to take the place of the water lost by evaporation. If the plant has large leaves, remove them; after the experiment is completed, draw their outline on cross section paper and find their combined surface. Compare it with the amount of water lost. At the same rate, estimate how much would be given off by a plant with a leaf surface ten times as great, or as many times as great as you please. Describe the whole experiment in writing, illustrating with sketches or photographs, as you please.

Cover a small fuchsia or balsam overnight with a bell jar. Where are the guttation drops found? Why do they form there? Cover young plants of oats, wheat, corn, or grass in the same way. Where are the drops formed on them? Make drawings of one or more kinds of leaves used in this experiment. Write notes telling what you discovered.

251. Structure of a Leaf (Cross Section). — While leaves vary greatly in number, size, position, and shape, the work that they do is very similar for each plant. A typical leaf is covered with a layer of thin cells called the *epidermis*. In hot, dry regions the epidermis has a heavy coating of cutin, a substance which prevents evaporation. The epidermis on the under side of the leaf is thinner and has less cutin than that on the upper side of the leaf. It is pierced by many openings called *stomata* (Greek, *stoma*, a mouth) which allow the entrance of air and the exit of water and gas. Between these two layers of epidermis is the *mesophyll* (mĕz′ō-fĭl: Greek, *mesos*, middle; *phyllos*, leaf) of the leaf, divided into two regions, (1) the upper or palisade composed of slender, elongated cells placed side by side in upright position, (2) *spongy layer* consisting of rounded cells, loosely arranged with many spaces between them.

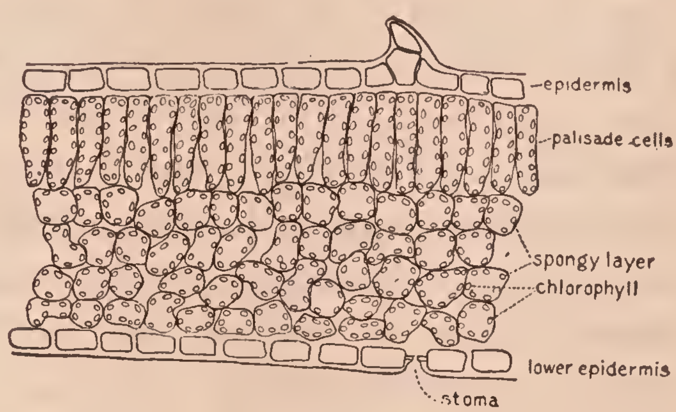


FIGURE 264. — CROSS SECTION OF BEAN LEAF.

How many tissues present?

Influences Affecting the Growth of Plants. — Experiments have already been performed showing that stems and leaves tend to turn towards the light (page 230), and that roots normally grow downward (page 230). The stimulus that causes roots to grow downward is gravity, and the response to this stimulus is *geotropism* (Greek, *ge*, earth; *tropos*, a turn). Response to the stimulus of light is known as *phototropism* (Greek, *phos*, light; *tropos*, a turn), while that of the sun is known as *heliotropism* (Greek, *helios*, sun; *tropos*, a turn). When roots turn aside to avoid an obstacle and when tendrils or climbing stems clasp a support, they are acting in response to the stimulus of contact, the root acting negatively and the tendril and stem positively. This response is known as *thigmotropism* (Greek, *thigmos*, touch; *tropos*, a turn). In general, plants or parts of them show positive thigmotropism towards stimuli that are helpful and negative thigmotropism towards those that are harmful. The roots of the elm and the poplar trees which force their way into sewer pipes through a joint and then fill it with roots are acting in response to the stimulus of the presence of water. This is known as *hydrotropism* (Greek, *hydros*, water; *tropos*, a turn).

LABORATORY STUDY OF LEAVES

Draw a leaf of geranium (or other plant). Label (1) blade, (2) petiole, (3) stipules, if any. Notice the arrangement of the veins as you look through it.

Remove the leaves from an onion. Note the thickened bases and how they are attached to the short stem.

Stand a stalk of celery in water tinted with red ink. Cut across it after two hours and observe the position of the vascular bundles. Trace them into the leaf.

Pull off leaves of dock and plantain and observe the tough vascular bundles.

Study a bit of epidermis with a microscope. Draw. Label stomata, epidermal cells, guard cells (2 around each stoma). Study a cross section. Label *cuticle*, outermost layer, *epidermis* (upper and under

surfaces), *palisade layer* under top epidermis; *spongy layer*, body of leaf; *vein*. Which cells contain chlorophyll?

HOME WORK ON LEAVES

Pull up or cut off a large burdock plant. Measure the area covered by the lower leaves. What else grew in this area? What is its condition? Why? Do the same with plantain, dock, dandelion, knotweed, and other weeds in dooryard or garden. What plants form rosettes of leaves in the fall?

Break off leaves of burdock, plantain, dock, and pieplant. Note the strings (fibrovascular bundles).

Make a collection of leaves to illustrate the various kinds of shape, apex, margin, and base.

Study the arrangement of leaves on the plants you see to determine how it is adapted to secure light for all the leaves.

What effect does the wind have in helping or hindering leaves to get light?

What happens when you make a "bag" from a leaf of live-for-ever?

How can you tell guttation drops from dew?

252. Adaptations of a Leaf. — The cutin of the epidermis prevents evaporation of water. The stomata allow air to enter and water and gases to pass out. Stomata themselves show many adaptations: (1) *Position.* In a leaf that extends horizontally from a plant, most of the stomata are on the under side, an adaptation which prevents their being closed by water. In leaves which float upon the water, the stomata are on the upper surface for the same reason. In plants with erect leaves, the stomata are distributed on both sides. In the cases of desert plants, the stomata are sunk below the level of the epidermis, or they are covered by hairs or wax, both of which tend to keep them from being filled with water and to prevent undue transpiration (evaporation). (2) The *structure.* This shows other adaptations. The opening is surrounded by two cells, called *guard cells*, which have the property of absorbing water from the atmosphere. When these cells are full of moisture, they are plump or *turgid;* when they have only a little water they are flabby

or *flaccid.* The turgid guard cells leave the stomata wide open and allow free passage of air into the cell, and of water and gas out of it. Flaccid guard cells, on the other hand, make the opening small, decrease the amount of air that enters, and prevent undue evaporation from the inside of the leaf. Although each stoma is very small, they are so numerous that their combined action accomplishes a great deal. A square millimeter of the under surface of a lilac leaf contains 330 stomata, that of white birch, 237.

FIGURE 265. — LEAVES OF BARBERRY.

These leaves, all taken from the same bush, show the transition from normal leaves to thorns for protection.

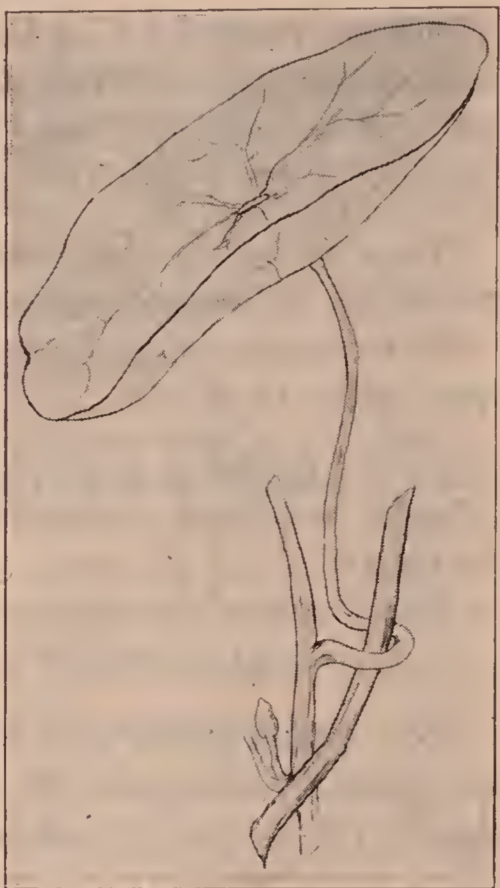


FIGURE 266. — PELTATE LEAF OF NASTURTIUM.

The petiole is attached at the middle of the back of the blade. The blade is orbicular, with entire margin. Note the twining petiole, a device for holding up a weak stem.

Most of the grasses show adaptations (1) in having very narrow leaves, fitted to grow close together; (2) in wavy edges if they are long, an adaptation which prevents their being torn by the wind; (3) in a clasping base, helping to strengthen the stem, and (4) in a collar which prevents water from running down between the clasping base and the stem.

253. The Arrangement of Leaves. — Whatever the arrangement of leaves on any particular plant, the object is to expose the leaves most advantageously to light and air, incidentally preventing their shading one another, which sometimes causes a vertical branch and a horizontal branch of the same plant to show a different arrangement of leaves. In general, leaf arrangement falls into two groups: (1) small leaves arranged all along the length of a branch — the spiral arrangement, the simplest form of which is found in the elm where the leaves are in two rows alternating with each other; (2) a few large leaves at the end of a branch, as in the maple, where the leaves are in pairs, each pair alternating with its neighbors. In the first case the shape of the leaves is such that all the space is occupied without much overlapping; in the second, every leaf is fully exposed to the light by the lowest leaves having the longest petioles. (See Figure 269.) The leaves of a maple illustrate this. A rosette is formed by leaves, arranged spirally on a very short stem, with long petioles nearest to the ground, shorter ones alternating with them and filling the spaces. The dandelion, evening primrose, and thistle show rosettes. Light that has passed through one leaf is of little value to a leaf below it. Some plants have finely divided leaves, an adaptation which prevents any leaf shutting off all the light from those below. Angular leaves, round leaves, and leaflets are all adaptations to use up all the space without overlapping.

FIGURE 267. — TWINING PETIOLE OF CLEMATIS.

254. Peculiar Uses of Leaves. — Some leaves, like the sundew, pitcher plant, and Venus's flytrap, are adapted for catching insects for the use of the plant as food (see page 366). In

others, as clematis, the petioles are used to help the plant in climbing. In the pea and grape, leaves have become modified into tendrils which are used in helping the plant to climb. (See Figure 270.) Still others have their leaves modified to thorns for protection, as in the thorny locust.

FIGURE 268. — INDIAN PIPE.
A saprophytic flowering plant.

255. Leafless Plants. — In plants like the cactus, already mentioned, the work usually done by leaves is performed by the stem. Asparagus is a plant in which a much-branched stem serves as leaves, the true leaves being almost invisible scales. Another example is the plant commonly called smilax, in which the branches very closely resemble leaves.

Other plants which have scales instead of leaves are dodder and Indian pipe, both of which use food already prepared.

256. The Movement of Leaves. — Most movements of leaves are due to unequal growth caused by the light being brighter on one side than on the other. Some leaves on this account "follow the

sun." Others, like the compass plant, turn their edges to direct sunlight which is too strong for them. The clover and oxalis, which fold their leaflets at night, illustrate the so-called "sleep movements" of plants. The movements of sensitive plants are due to the effect of the shock caused by

FIGURE 269. — LEAVES OF YOUNG PLANTS OF POKEWEED.

Note their large size, and their arrangement to prevent shutting off the light from those below. Contrast these leaves with those of Indian Pipe. This plant has mere scales in the place of large leaves, and they lack chlorophyll, the plant being pure white. It cannot manufacture food for itself, but depends on decaying organic matter in the soil.

touching them. This causes the cells of an organ at the base of the petiole, called the *pulvinus*, to become soft and flaccid through loss of water which passes into the inter-cellular spaces, allowing the whole leaf to droop and the leaflet to fold.

HOME WORK, MOVEMENTS OF PLANTS

Place young seedlings in a window for a day. Which way do they turn? Turn the plants around and note how long it takes them to become erect; to become bent towards the window again.

On a sunny day set a stick parallel with the tip of a ragweed or other tall, slender weed. Set another stick about noon and another about three o'clock. Draw a diagram, or use your camera to show the changes in the position of the tip of the plant. Observe leaves of clover, and young daisy blossoms. Do they change their positions with the sun? What other plants do this? Does the age of the plant make any difference with its ability to change position?

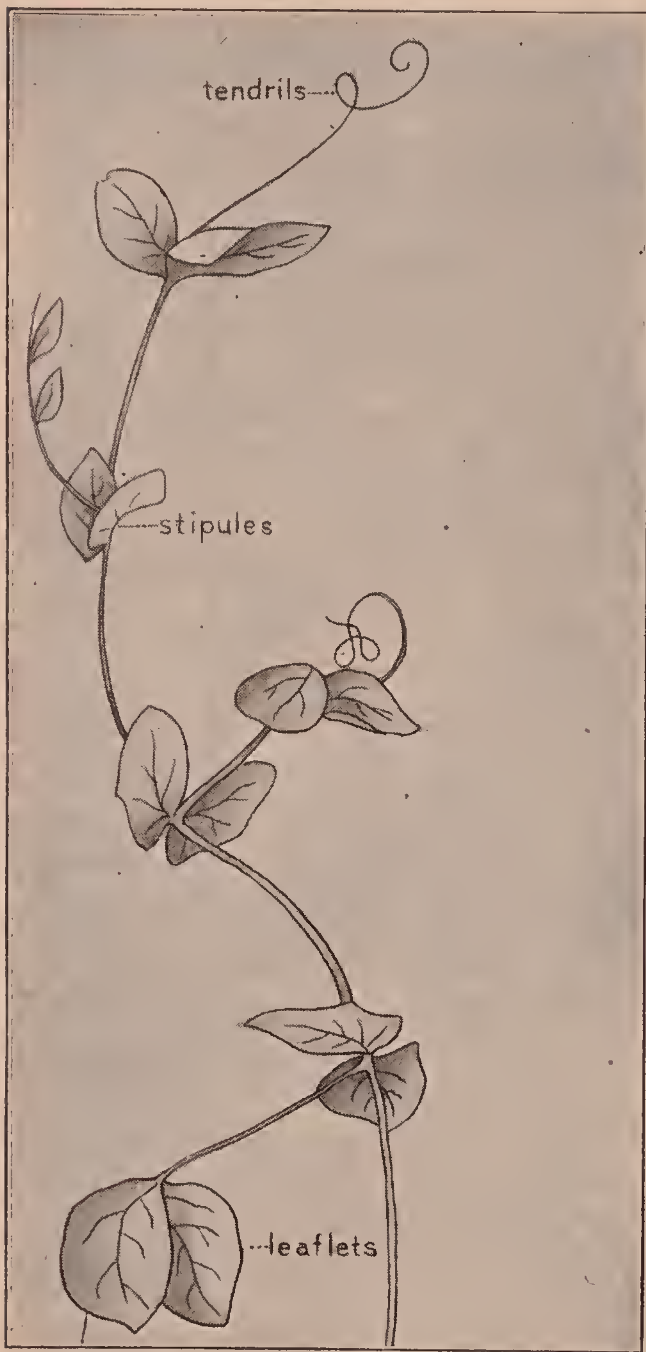


FIGURE 270. — PEA PLANT.
The leaves are modified into tendrils for climbing.

Bend a grass stem and fasten it flat. After a day or two observe its position. What changes have taken place? Remove the clasping leaf base and see what part of the stem was able to bend.

Write notes telling what you have been able to observe in the cases above, and in any others which you may have noticed without being directed to do so.

257. Economic Uses of Leaves. — The leaves of all the grasses as well as their stalks are used as food for cattle. Man uses for food the leaves of cabbage, lettuce, spinach, celery, parsley, kale, kohlrabi, and Swiss chard; and as a beverage, the leaves of the tea plant. The leaves of some of the mints, spearmint, wintergreen, peppermint, and sage, are used for flavoring, and the leaves of some plants, mullein, bone-

set, catnip, peppermint, wintergreen, and wormwood, for medicine.

258. **The Blanching of Celery** is a practical application of the fact that chlorophyll cannot develop in darkness. The stalks are either covered with earth, or the rows of celery are shut in from the light by long strips of black paper which allow only the top leaves to project into the light. The white leaves in the heart of a head of cabbage, lettuce, or in opening buds in the spring are also accounted for by the fact that they are shut off from light by the leaves which surround them.

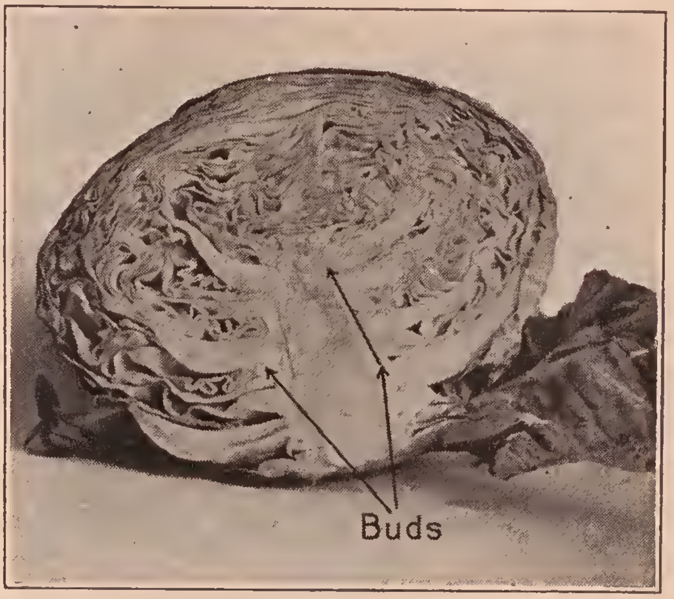


Figure 271. — Vertical Section of Cabbage.

The thickened bases of the leaves are used for food storage. The stem of a cabbage is short, and the bud very large in proportion. Note the buds in the axils of the leaves.

SUMMARY

The leaf is the organ of greatest use to the plant in performing the processes which maintain its own life. In the leaf food is manufactured, digested, and assimilated. Its cells carry on excretion and respiration to a greater degree than any other cells of the plant.

The purpose of the shape, size, and arrangement of leaves is to enable them to get the greatest amount of light and air possible.

On the process of photosynthesis depends the whole world's supply of food.

QUESTIONS

Name the processes carried on by the leaves. Which is of the greatest use to man? Why? What is the object of leaf arrangement?

Describe the structure of a leaf. What two purposes are served by veins? Mention at least four plants that have peculiar leaves. Describe each and tell how it helps the plant.

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CHAPTER XXI

OTHER FLOWERING PLANTS

259. The Flowering Plants. — True flowering plants are the most highly developed of all. They are numerous, it being estimated that there are 120,000 kinds. Some varieties are so small as hardly to be noticed, while others, like the hardwood trees, are very large. Some live submerged in water, while others are found only in deserts.

FIGURE 272. — WALNUT TREE.

The flowering plants are of special interest on account of their intimate relation to our daily life, and on account of this close relationship we should study some of the most common families, such as the grass, rose, mustard, and the like, all of which are easily recognized.

The Grass Family. — The grass family has long narrow leaves with clasping bases and parallel veins, fibrous roots, and inconspicuous flowers which are pollinated by the wind. The grasses are the most important of all plants as food for man and the animals which he uses. This family includes corn, wheat, oats, barley, rye, rice, and similar grains. The corn plant was found growing in America when the New

World was discovered, and it was one of the principal foods of the Indians. Now corn is grown wherever the season is not too short for it to come to maturity.

Most of the work of planting, cultivating, and harvesting corn is done by machinery. Hand work is necessary only in removing the ears from the stalk and the husk from the ears. Because corn is so valuable a food for men and animals and because so much of the work necessary in raising it can be done by machinery, corn raising has become one of the most important industries on the easily cultivated level prairies of the Middle West. Wheat and barley are mentioned in the earliest literature and were among the first plants cultivated for food. As men learned to till the soil and harvest these grains, agriculture became established and a marked step towards civilization was made. In China and India millions to-day depend very largely upon rice.

FIGURE 273. — LEAF OF OAK. A simple leaf with a lobed margin.

An idea of the importance of the cereals as food crops can be gained from the following statistics as shown by reports in 1918.

Rice,	41,918,000	bushels
Wheat,	918,920,000	"
Oats,	1,535,297,000	"
Rye,	76,687,000	"
Barley,	236,505,000	"
Corn,	2,717,775,000	"

These are for production in the United States alone. Certain localities lead in the production of each grain.

Lily Family. — Lilies have parallel-veined leaves. The flowers are made up of a six-parted *perianth* (calyx and corolla taken together), six stamens, and a three-parted pistil. The fruit is a capsule. Lilies are cultivated chiefly for decorative purposes.

FIGURE 274. — SILIQUES OF WHITE MUSTARD.

Walnut Family. — The trees of this family furnish us with nuts and valuable lumber. The monœcious flowers (see page 204) are grouped in catkins. The leaves are alternate and pinnately compound (see page 277). All the walnuts and hickories belong to this very useful family (Figure 272).

Beech Family. — Like the walnut family, this group consists of trees, of which the beech, oak, and chestnut are the most common. All are valuable for lumber and firewood. The leaves are simple, alternate, and straight-veined. The flowers are monœcious.

FIGURE 275. — SINGLE SILIQUE SPLIT OPEN.

Crowfoot Family.— This large family is valuable to us for the medicines (mostly poisonous) which it furnishes. The medicinal members of this family are hydrastis, aconite, hellebore, and larkspur; while other members, as clematis, peony, and columbine, are cultivated for ornament. The common buttercup shows most of the characteristics of the crowfoot family. The leaves are commonly dissected; the petals, sepals, and pistil are all disconnected (see page 198). The juice of the buttercup is colorless and is biting to the taste.

Mustard Family. — Garden vegetables such as the turnip, radish, cabbage, horse-radish, and mustard belong to this family. All have regular flowers consisting of four sepals, four petals, and six stamens. The corolla is in the form of a Greek cross. These plants have a pungent, watery juice which is non-poisonous. The fruit is a kind of pod called a *silique* (see page 297).

Rose Family. — The flowers are regular with the calyx usually of five sepals and the corolla of five petals. The leaves are alternate and usually serrate on the edge (see Figure 276). The rose family is as important in furnishing the luxuries of our food as the grass family is for supplying the necessaries. To this group belong all the common orchard fruits, such as apples, peaches, and plums, and many of the so-called berries, such as the raspberry and strawberry. Many of the members of this family are also cultivated for ornament.

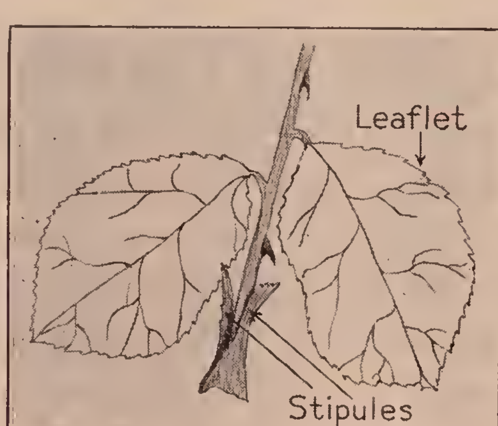

FIGURE 276. — BASE OF COMPOUND LEAF OF ROSE, SHOWING STIPULES.

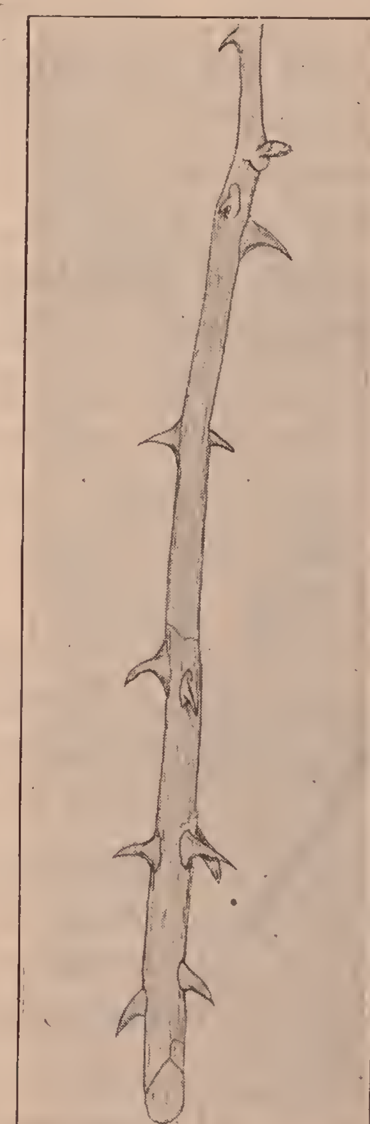

FIGURE 277. — STEM OF ROSE.

The thorns which are outgrowths from the epidermis are adaptations for protection.

FIGURE 278 — NODULES CAUSED BY BACTERIA ON THE ROOTS OF BEAN PLANTS.

Pulse Family.—Beans, peas, vetch, alfalfa, peanuts, clover, and the like are members of this family. These plants may be recognized by their irregular, papilionaceous flowers, alternate leaves with stipules (see Figure 292), and by their having the fruit in the form of a pod. This family furnishes us with most of our vegetable protein food. The plants improve the soil by the aid of bacteria. Wisteria, red bud, and the locusts are cultivated for ornamental purposes.

FIGURE 279. — PEANUT.

After the ovules are fertilized the plant pushes the pistils into the soil, where they mature. Note the nodules on the roots. The peanut is a dry, indehiscent fruit.

Flax Family. — While this is not a large family, yet it furnishes all of our linen. Flax rarely grows wild, but requires cultivation.

Mallow Family.—This family is also important in furnishing material for our clothing, as the cotton plant belongs here. Hollyhock and althæa are forms cultivated for ornament.

Parsley Family.—This family includes such gar-

den vegetables as parsnip, parsley, and carrots, and plants like fennel, dill, coriander, and caraway used for medicine and for flavoring food. These plants have hollow, ribbed stems, alternate, compound leaves, and flowers in an *umbel* (see Figure 201).

Mint Family. — The members of this family are easily recognized by their square stems, opposite leaves with

FIGURE 280.— FLOWER OF COLUMBINE.

Showing spurred petals. Only a long-tongued insect can reach the nectar. Note the bunch of stamens upon which the insect alights.

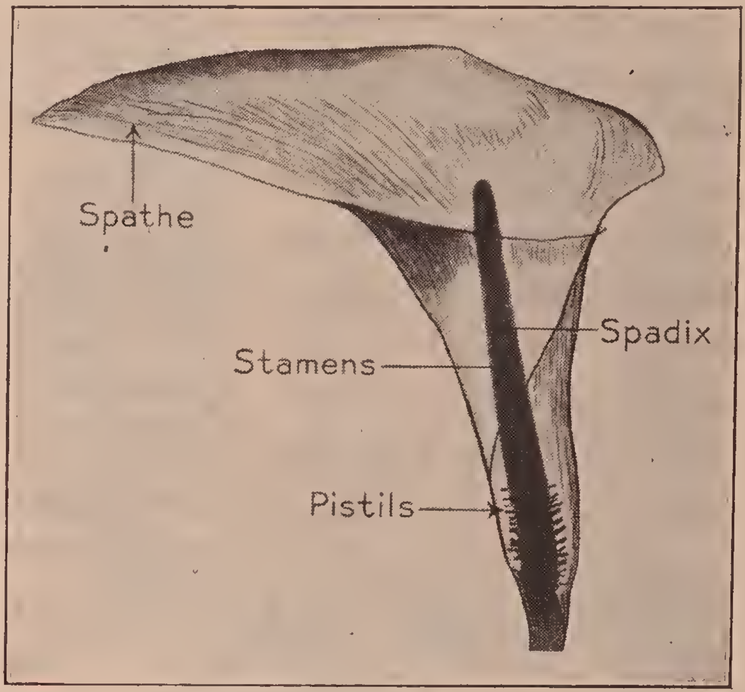

FIGURE 281.— CALLA, A FLOWER WITH SPATHE AND SPADIX.

Representing a group of tropical plants of which Jack-in-the-pulpit is a common example in New York State. The spathe is a modified leaf.

crenate margins, and bilabiate flowers (an irregular flower divided into two parts, see Figure 193). Peppermint, spearmint, catnip, horehound, pennyroyal, sage, savory, and thyme are some of the mints used for medicine and in food.

Nightshade Family. — Here are found many poisonous plants, as tobacco and Jimson weed, from which stramonium

(similar to belladonna but more powerful) is obtained. The tomato, potato, and egg-plant are used for food. Petunias are cultivated for ornament. The foliage of all these plants is rank-scented, the leaves are alternate, and the tubular flower five-parted.

The Composite Family. — This family is typified by the common daisy and dandelion. They have their flowers in

FIGURE 282. — COMMON FIELD DAISY.

heads. These are of two kinds, ray-flowers and disk-flowers (see Figures 190, 191, and 192). This is one of the largest families of plants, and, from the standpoint of the botanist, the most complex. It contains our common weeds, such as daisy, dandelion, goldenrod, aster, burdock, thistle, and hawkweed.

Not all the flowering plants are beneficial to man, and every farmer and gardener has to struggle with the weeds. Some of the members of the composite family, like the goldenrod and daisy, lend a charm to the fields, and many

people dislike to think of them as obnoxious plants. But they prevent the grass from growing, and cattle will not eat them either in the winter or in the summer, so that they are a nuisance to the farmer. A weed, then, may be defined as a plant which interferes with the growth of some useful plant. Weeds are successful in growing and in living, because they have strong roots, produce many seeds, and have numerous devices for distributing their seeds.

HOME WORK

Consulting any maps which show where most of our common food plants are raised, make a note of the states which produce the greatest quantity of each. What is the leading industry in these states? What industries are related? Why? Find pictures showing how some of these crops are harvested. What industries are concerned with manufacturing the products of these states? What one in distributing the manufactured products? By what routes are most of them shipped? Why? What are the leading crops in your township? in your county? in your state? What foods do you have to bring from other states? Why? Try to think how climate, kind of soil, and the needs of the community influence the farmer as to the kinds of crops he plants. Notice what he does with the surplus. Find out from government reports how much grain was sent to Europe during the war. Find out how the number of bushels of grain produced per acre compares with that in other countries. Account for the facts you learn. How can a knowledge of biology help a farmer?

SUMMARY

The flowering plants are the most highly developed of all the plants and bear an intimate relation to mankind. The many grasses and cereals furnish animals and man with much of their food. The cultivation of these plants has aided the development of civilization.

QUESTIONS

What plants furnished part of your food to-day? In what part of the plant was this food made? In what part stored? What fruits do you eat? Which plants grow these fruits? Where do these plants live? Name plants, parts of which are used in medicine. What plants are used

in making paper? What parts of a plant are used in making houses? What kinds of cloth are made from cotton? from linen? from silk? from wool? What are the common weeds?

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CHAPTER XXII

THE SIMPLEST GREEN PLANTS

260. Introduction. — Many plants never have more than one cell and are so small that they can be studied only through a microscope. All these minute plants have long scientific names, often hard to remember, but they are the same names which the English, German, or Japanese children have to learn when they study these plants.

The two plants discussed in this chapter belong to the group known as the *Green Algæ* (Latin, *algæ,* seaweed). The names of these two plants are *Pleurococcus* (plū-rō-kŏk′ŭs) and *Spirogyra* (spī-rō-jī′ra).

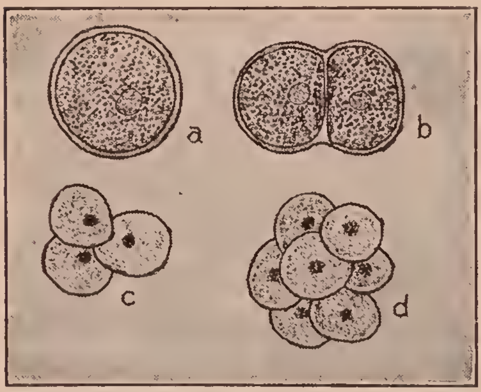

FIGURE 283. — PLEUROCOCCUS. *a,* single plant; *b,* plant dividing; *c, d,* groups of plants.

We are now to compare these microscopic plants with such larger plants as lily and nasturtium, each of which, composed of hundreds of cells, is able to respire, make its own food, and produce seeds.

261. Pleurococcus. — Pleurococcus is a widely distributed, single-celled plant which grows in great abundance upon the shady side of trees, old buildings, and rocks. After a rain it is conspicuous in these places as green patches. A bit of this green substance examined with a microscope shows many green cells. Each plant or, we may say, each cell is a somewhat roundish structure with a clearly defined cell wall. The contents of the cell are green, due to the chlorophyll which conceals all parts of the cell except the nucleus. The nucleus usually lies near the center of the

cell. As long as the cell is full of chlorophyll, the cytoplasm cannot be seen (Figure 283).

Pleurococcus makes its own food as larger plants do, and it is able to digest the starch and protein which it makes. Whenever a number of pleurococcus cells are examined, some are found to be dividing. In this division the nucleus forms two nuclei which move apart. A partition wall forms and two cells take the place of the old or parent cell. This method, called *fission* (Latin, *fissus*, cleft), is the simplest form of reproduction. It is a form of asexual or vegetative reproduction, as it takes place without the union of egg and sperm. In pleurococcus the cells do not always separate at once, but form groups of two, three, or more cells (Figure 283).

SUMMARY

This simple unicellular (one-celled) green plant, pleurococcus, lives and makes its own food and produces new cells. While there are no flowers and seeds as in the plants already studied, yet this plant is able to reproduce itself. All the important life processes found in plants take place in the simple, single cell.

LABORATORY STUDY OF PLEUROCOCCUS

Study this as an example of a plant which consists of a single cell, but still performs all the processes common to complex plants. Soak a bit of bark and scrape it gently to get the pleurococci cells, some of which may be in groups. Place on a slide and examine with high-power microscope. Draw a single cell and a group of cells. Label cell wall and nucleus.

262. Spirogyra. — This plant is best known as the " pond scum " which grows in most fresh-water ponds and in slow-running streams. It may be kept for some time in glass dishes in a laboratory. Instead of being made up of round cells or clusters of cells, the cells of spirogyra are cylindrical in shape and are attached end to end. This results in long,

fine threads called filaments which float in the water in large masses. Spirogyra is only one of many kinds of filamentous algæ.

The individual cells of spirogyra are provided with one or more narrow green bands arranged spirally within the

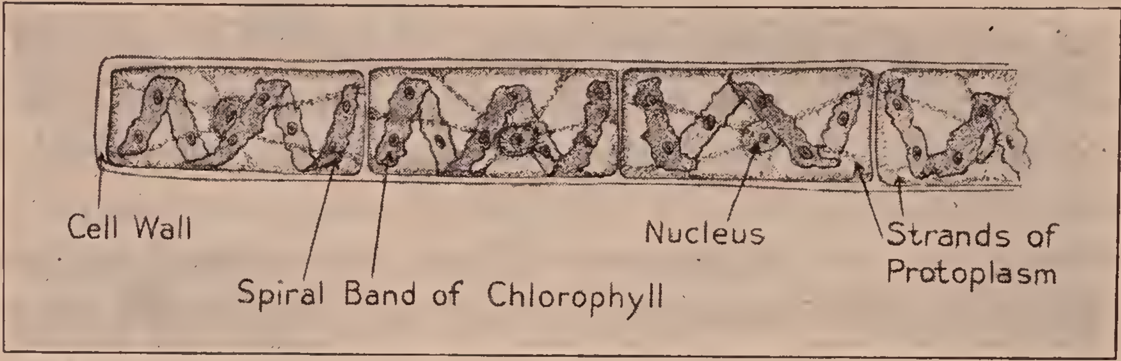

FIGURE 284. — SPIROGYRA.

protoplasm. These spiral bands of chlorophyll are the special structures which manufacture food (Figure 284). The cells of the filament increase rapidly in size and divide, and thus the filaments increase in length. As each cell divides, the cell wall grows in at right angles to the length of the plant. Spirogyra grows very rapidly in the spring. The bubbles found among a mass of spirogyra contain the oxygen which the cells give off during photosynthesis.

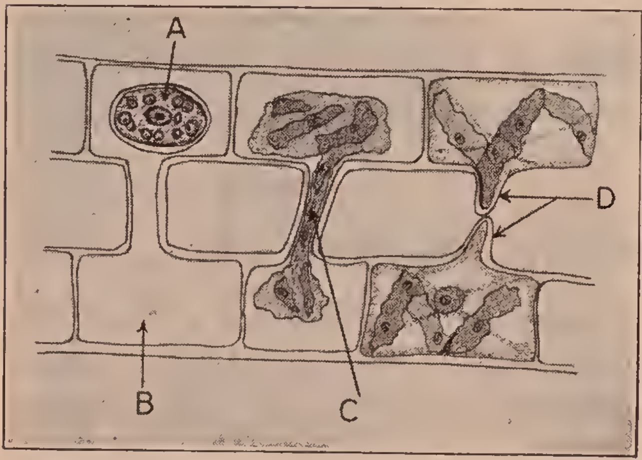

FIGURE 285. — SPIROGYRA CONJUGATING.
A, zygospore; *B*, empty cell; *C*, canal formed by tubes; *D*, tubes.

During the summer there are times when spirogyra reproduces in another manner (Figure 285). Two cells of adjacent plants join by putting forth tubes which fuse on meeting. The contents of one cell pass through the tube, and flow into and unite with the contents of the other

cell. Thus there is formed a single roundish mass of protoplasm surrounded by a thick wall. This mass of protoplasm is called a sexual spore, because two cells unite to form it. The two cells which thus unite are called *gametes* and are identical in all their parts. This spore, therefore, is known as a *zygospore* (Greek, *zygos*, yoke; *spora*, seed). In the formation of a zygospore, the cells are joined permanently and a simple form of sexual reproduction is present.

As a zygospore, spirogyra can live in a resting condition during periods unfavorable to its growth, as in winter or during a drought. When conditions again become favorable the zygospore germinates and grows into a filament. The spirogyra is able to do the same things which a pleurococcus does and has the same life processes.

LABORATORY STUDY OF SPIROGYRA

Notice: (1) the clear outer part called the *cell wall;* (2) the main mass of the cell, a substance called *cytoplasm.* (This can be easily seen by putting a 5 per cent sugar solution under the cover glass. The cytoplasm draws away from the cell wall into a compact mass in the center of the cell.) (3) The darker portion, the *nucleus*, in or near the center of the cell. (This can be clearly seen by putting a drop of weak iodine under the cover glass, using fresh material for this test.) (4) A spiral band of green coloring matter, chlorophyll, containing bright spots.

Examine spirogyra in a mass, floated out in water in a glass or on a plate. Feel it and observe that it is slimy. Note its color and delicacy. After it has been in the sun for a time, note the bubbles of gas entangled in the spirogyra, which help to make it float. With a microscope examine filaments which are joined in places by outgrowths from other filaments. Such filaments are said to be in conjugation. Draw the outgrowing tubes, the empty cell, and the zygospore or zygote. Label all.

263. Economic Importance of Algæ. — Although algæ are so small they sometimes make trouble by causing the water stored in reservoirs to have a fishy taste and smell. This is due to substances formed during their rapid growth, not harmful, but unpleasant. A very small quantity of copper

sulphate in the water kills the plants without making the water unsafe for drinking purposes. A canvas bag containing crystals of copper sulphate is dragged through the water by men in a row boat.

SUMMARY

Both pleurococcus and spirogyra are called algæ, and each is typical of many other plants of the same kind. Our chief interests in them are that they are adapted to very simple conditions for living, and that each cell is capable of carrying on all the life processes for itself. Plants like pleurococcus are called unicellular; those like spirogyra, which consist of many cells joined end to end thus forming a strand, are called *filamentous algæ.* Pleurococcus is found on old buildings, fences, posts, rocks, and on the bark of trees. It shows more plainly in wet weather than in dry, for then it is growing. Spirogyra grows in running water, attached to objects on the bottom, or floats in masses on the surface of ponds, ditches, and sluggish streams. Neither of these plants has any economic value, but some algæ cause drinking water to have an unpleasant taste and smell.

Algæ are simple plants which grow in water or in moist places. Fresh-water algæ are usually small. Algæ illustrate how a plant cell carries on the life processes. The cell is the unit of plant structure, and plant cells are similar to animal cells in all essential respects.

QUESTIONS

What is a cell? Compare plant with animal cells. Explain the process of conjugation. In what respects is the formation of a zygospore similar to the process of fertilization in a flowering plant?

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CHAPTER XXIII

SMALLEST PLANTS (BACTERIA)

264. Bacteria. — Bacteria are the smallest of all plants, — so small that they can be seen singly only through the aid of a powerful microscope. We do not know all about their life processes, but we have learned much about their effect. We constantly hear about these plants, either under their correct name, *bacteria*, or under the names of *germs* or *microbes*. Two incorrect ideas concerning bacteria are prevalent, — one, that bacteria are animals, and the other, that all are harmful. It is definitely known that bacteria are plants; that small as they are, they are among the most important plants in the world; that most of them are helpful, and only a few harmful. They are, however, so much like the one-celled animals (protozoa) that the word *germ* is not unnaturally used to cover both.

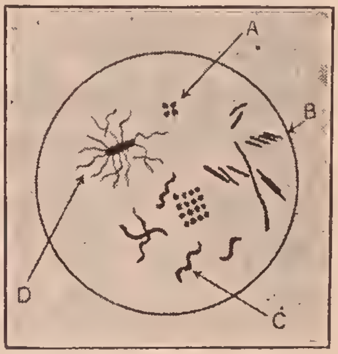

FIGURE 286.

A, cocci; *B*, bacilli; *C*, spirilla; *D*, bacillus with flagella.

265. Shape and Size of Bacteria. — Bacteria, according to their shape, are grouped into three classes: (1) round (the cocci); (2) rod-shaped, like a short unsharpened pencil (the bacilli); (3) those that are shaped like a corkscrew (the spirilla). Most of the names for the different bacteria contain one or another of these words, thus indicating the shape of the bacterium[1] under discussion. The spirilla and the bacilli often have on one or both ends tiny thread-

[1] Bacterium, singular of bacteria.

like hairs by which they move, giving the first observers reason to think that they were animals.

To show how small bacteria are, fifteen hundred of the rod-shaped form will hardly reach across the head of a pin. When bacteria are grown in the proper kind of substance, there are so many in a cluster that they appear as tiny spots or points, often tinged with a faint color. When seen alone under the microscope, they are clear, almost transparent, and colorless, and often have a bright, shining spot on the inside.

266. Where Bacteria Are Found. — Bacteria are everywhere, — in the air, as invisible dust; in the upper layers of the soil; and in water. We breathe in the microbes of the air with every breath, but generally with no injurious result. Every bacterium has its own work to do, and a healthy body gives little opportunity for most kinds of bacteria to do harm.

267. Conditions Necessary for the Growth of Bacteria. — Like all other plants, bacteria must have all the proper conditions before they can grow and multiply. Their food is chiefly plant or animal matter, but they cannot make use of food except in the presence of warmth and moisture, and most of them require oxygen in addition. They get the oxygen from the surrounding air.

268. Life Processes. — In the preparation of their food bacteria break up organic substances, that is, decompose them, causing the condition known as decay. They use some of the material resulting from decay; some they set free in the air; and the remainder is left on the earth to be used by more complex plants. In changing dead matter — plants, leaves, and animals — to a form which again becomes a part of the earth, bacteria perform a service valuable to man.

Reproduction occurs in bacteria through simple fission. Sometimes bacteria break entirely apart, while in other

cases they remain connected, forming a chain. Under favorable conditions each cell can grow to full size in half an hour and be ready to divide again. It is this ability to multiply rapidly which makes them of so great importance, for a few hundred bacteria, even of the harmful ones, could produce little effect.

In the process of growth, bacteria produce two substances, *enzyme* (see page 14) and *toxin* (tŏx'ĭn: Greek, *toxicon*, poison). Enzymes produce fermentation, a breaking-up process of which man makes use to secure certain flavors and odors, as well as to soften hard materials. Toxins are usually poisonous to living organisms, including the bacteria which produce them.

Enzymes cause the pleasant flavor of such articles of food as cheese and butter. The quality of tobacco depends largely upon the kind of bacteria which have been at work upon it. Such bacteria are classed as helpful, as are those which gather nitrogen for the plants of the bean family. Other helpful bacteria are those which make it possible for man to use sponges by ridding them of the soft, slimy substance with which they are filled when alive, as well as the bacteria which soften the useless parts of the flax plant so that the rest of it may be separated and made into linen.

When food, air, warmth, or moisture is not sufficient, bacteria cease to grow and go into a resting state. That is, they change their form, and surround themselves with a substance which protects the soft protoplasm from being harmed by freezing, heating, or drying. The simple plants all do this, but the simpler the plant, the more easily does it resist. It is this ability to withstand unfavorable conditions and to resume growth when conditions change for the better that makes bacteria "such good friends and such bad foes." Our ability to control them is due largely to a knowledge of their habits.

LABORATORY STUDY OF BACTERIA

Prepare culture plates of agar-agar from the following formula:

Agar-agar Formula for 1000 c.c.

Agar-agar[1]	15 grams
Beef extract	3 grams
Peptone	10 grams
Salt	5 grams
Water	1000 grams

Boil material for the agar-agar formula; add sodium hydrate till the color of litmus paper is not changed; cool to about 56° C., and beat into this one whole egg, including the shell. Warm slowly to the boiling point and continue till the egg is firmly coagulated; then strain the clear medium through a cheesecloth on to moist cotton in a filter funnel.

Work rapidly. Cool, and then boil once more. Filter through cotton into test tubes. Each tube should not be more than a quarter full. Plug the tubes with cotton. Then sterilize this mixture in the test tubes by placing them upright in water and boiling twenty minutes on each of three successive days. Let part of the test tubes cool, in a slanting position, having the plugged end elevated half an inch. These are called slant agar tubes. When petri[2] cultures are needed, melt up a sterile agar tube and pour into a sterile petri dish.

1. To show that bacteria are present on one's hands: draw the fingers of the unwashed hand across the surface of the agar-agar in petri dish; cover and set away for four days at room temperature or two days at body temperature.

2. To show that fewer bacteria are present on freshly washed hands: draw the fingers of the washed hand across the surface of the agar-agar; cover and set away.

3. To show that bacteria lodge under the nails, place on culture plates scrapings from under finger nails, (1) before washing the hands, (2) after washing the hands.

4. To show that heating milk reduces the number of active bacteria, sprinkle drops of milk and water mixture on agar-agar petri dish, (1) natural milk, (2) pasteurized, (3) boiled. (Use one tenth milk and nine tenths sterilized water.)

5. To show that bacteria change the medium in which they grow, note, besides the number, form, size, and color of the colonies, whether any change takes place in the agar-agar.

6. To show that bacteria grow best in the presence of warmth and moisture, compare those grown under such conditions with those grown

[1] Secured at most drug stores. [2] Flat, round dish with cover.

in a dry or a cold place. Note the influence (*a*) of warmth, (*b*) of cold, on the rapidity of growth.

7. To show that bacteria are in the air, expose the surface of the culture plate for a few seconds.

8. To show that flies distribute bacteria, let a fly walk across the surface of the agar-agar in the petri dish.

If bacteria have an opportunity, they work on everything which is capable of decay, so we need to know how to prevent their working upon food and other things which we do not wish to "spoil." Several ways in common use are: (1) cold storage, where there is not warmth sufficient for the growth of bacteria; (2) the use of salt and other chemicals to prevent their getting a start, as in the curing and smoking of meat; (3) drying fruit and meat, thus removing water, a necessary condition for growth; and (4) heating fruit, vegetables, milk, etc., and sealing them in cans or jars while hot, thus killing any bacteria the substances may contain and keeping all others out. Anything prepared in this way is preserved by being made *sterile* or *aseptic* (Greek: *a*, not; *sepein*, to make putrid).

269. Bacteria in Relation to Milk. — (See also Part III.) Milk as it comes from the healthy cow is practically free from bacteria of any kind. The number of bacteria present, however, is not of so much importance as the kind. But if a large number of bacteria are allowed to get into the milk, some of them are sure to be harmful and may find conditions so favorable for their growth as to make trouble for the person using the milk.

A high grade of milk will not contain more than 500 to 1000 bacteria per cubic centimeter. Such milk has been well cared for and comes from healthy cows. Some cities permit milk to be sold that contains as many as 100,000 bacteria per cubic centimeter and some even more. Such milk comes from unhealthy cows or dirty barns, or has been kept too long, or has "changed hands" too many times.

To deliver pure milk to the consumer costs the producer time, care, and money, and consumers should be willing to pay more for milk which has had proper care.

Ice prevents harmful bacteria from multiplying sufficiently to make milk dangerous, unless the milk is kept too long a time. Preservatives, soda, borax, boric acid, formaldehyde, and the like, are sometimes used to prevent the growth of bacteria. In some cases no immediate harm seems to come to the persons using milk thus preserved, but some of these substances are poisonous, and pure milk, properly cared for, does not need them. So the use of any milk in which preservatives are found should be avoided.

FIGURE 287. — BEEF JELLY. Exposed in unsanitary dairy.

A harmless bacterium gets into milk kept too long and forms lactic acid, thus giving the milk a sour taste and causing it to curdle. Sour milk is perfectly wholesome for food, but the taste is disagreeable. In 1857 Pasteur discovered this bacterium. He also found that milk could be kept for several days without becoming sour, after it had been heated sufficiently to kill this bacterium.

FIGURE 288. — BEEF JELLY. Exposed in sanitary dairy.

This process, called after its discoverer *pasteurization*, consists in heating milk for twenty minutes at a temperature of 60° C., or to a higher degree for a shorter time, and then cooling it rapidly. This procedure kills nearly all the bacteria in the milk and does not change the taste or make it hard to digest. Milk is not rendered absolutely

sterile, but it is a much safer food, especially for infants. At best pasteurization is only a corrective or precautionary measure, and we should demand that milk be kept clean and thus free from bacteria.

Most raw milk products have their own forms of bacteria, nearly all of which are helpful. The flavor of June butter is imparted by a bacterium different from the one in January butter. So with cheese, each brand or flavor receives its taste through the action of a special bacterium. At every step in the use and manufacture of milk, it is necessary to know the conditions under which the helpful bacteria work best, and how to keep out the harmful ones.

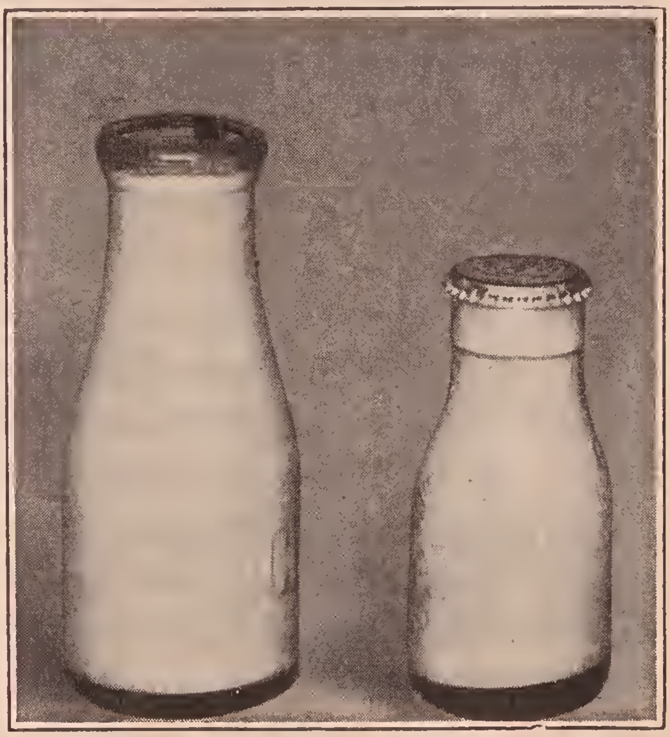

FIGURE 289.

The metal cap keeps out dirt which can get by the paper stopper.

270. Sources of Danger in Milk. — The cow herself may be unhealthy and her disease transmitted through the milk. Of the several diseases which this animal may give, tuberculosis is the most common. Children are more liable than adults to take the disease in this way. There is no necessity to be in doubt about a cow's being infected with tuberculosis, for in 1890 Koch discovered the tuberculin test, which enables the dairyman to detect the disease. This test is now commonly applied, and in some cities owners of herds which have been tested and found free from disease are allowed to sell their milk as "certified," though the meaning of this term varies. Not only is the raw milk from

tubercular cows dangerous, but also the butter and cheese made from it.

Bacteria multiply rapidly and remain active while milk is warm, consequently it should be cooled as soon as possible after it has been taken from the cow. Milk should not be used when it is too old, for in that case the harmless bacteria may all have died and harmful ones taken their places. Milk should not be left in a metal container, or open to the air, or placed in an ice chamber where it can absorb the odors of other foods.

Ice cream should be eaten only when fresh, for poisons (ptomaines) are formed by the action of bacteria, especially in ice cream which has been melted and then refrozen. Ice cream should be made under clean and healthful conditions, and should never be exposed to the air of the street.

271. Men Who Made the Study of Bacteria Possible. — The inventor of the microscope should be placed at the head of the list of men who made the study of bacteria possible, for without this instrument we should not know that such plants exist. We do not know who the actual inventor was, but the microscope was little more than a toy until it was improved by a Dutch naturalist, Leeuwenhoek (Lŭ′wĕn-hook), in the latter part of the seventeenth century. Next in the study of bacteria comes Pasteur, who discovered and studied them in their relation to the souring of milk and in other fermentations. Next comes Koch, who discovered a way of separating bacteria so that each kind may be studied by itself, a method called getting a "pure culture." He also invented the tuberculin test. Most of our facts about bacteria have been learned during the past thirty-five years, since men have learned how to prepare them for study.

272. Healthy Bodies and Bacteria. — So much has been said about harmful bacteria that a word of caution is needed. Two facts should make us take a sane view of the situation: (1) for every harmful bacterium there are thousands of

helpful ones; and (2) harmful ones cannot do their work, or even live, in a perfectly healthy body, for such a body is constantly preparing a substance (antitoxin) which neutralizes the bacterial poison (toxin). Our chief aim, then, should be to keep well, and a few simple rules of hygiene will accomplish this. (1) Spend as much time as possible exercising in the open air. (2) Sleep as many as eight hours out of twenty-four in a well-ventilated room or out of doors. (3) Eat only food which agrees with you, and not too much of that. (4) Wear seasonable clothing. (5) Keep the skin clean through frequent bathing. (6) Have a definite occupation, work faithfully at it, do your best, and don't worry.

SUMMARY

The smallest and simplest of all the plants are the bacteria. Most of them are helpful, ridding the earth of waste material, giving flavor to food, gathering nitrogen from the air for plants, and aiding in the making of linen and sponges. Some bacteria are harmful and cause diseases in plants and animals. Bacteria are spherical, spiral, or rod-shaped. They are found everywhere, unless special pains have been taken to remove them. If they have plenty of food, air, moisture, and warmth, they multiply rapidly, and they go into the resting state, in which they can remain for a long time if any or all of the necessary conditions of growth are lacking. The harmful bacteria during their growth secrete a poisonous substance, toxin. When there are enough bacteria present to make a large quantity of toxin, the animal or plant host is made ill. Some bacteria, especially in the resting state, can bear freezing or boiling without being killed. In order to make anything "keep," it is necessary either to kill all the bacteria by making the substance sterile or aseptic, or to put into it a preservative, a substance in which the bacteria cannot grow. We should use great care to avoid the bacteria known to produce disease.

Milk, one of the most important articles of food, is a possible source of danger from harmful bacteria which may get into it in various ways. Milk should be kept cold, and should be used before it is too old. The harmless bacteria in milk form lactic acid and cause the milk to sour. The growth of these bacteria can be checked by pasteurizing the milk. Ice cream, if too old, is dangerous, for the slow-growing bacteria have had a chance to develop.

The men who did the most to make the study of bacteria possible were Leeuwenhoek, who improved the microscope; Pasteur, who discovered bacteria in milk, and Koch, who found the way to make a pure culture and to test cows for tuberculosis. Many students are devoting their lives to the study of the various bacteria.

Every one should know the main facts about bacteria so that he may not have a foolish fear of them, but may be able to take reasonable precautions against the harmful kinds. Since a healthy body is the best safeguard against harmful bacteria, we should observe the laws of hygiene in order to keep well, and at the same time avoid, when possible, the bacteria which produce disease.

QUESTIONS

What are the main points of likeness between a bacterium and a flowering plant? What has the pleurococcus which the bacterium lacks? How can food be protected from harmful bacteria? In what respects are bacteria harmful to milk? In what respects helpful? Why are a few harmful bacteria not injurious in a healthy body? If one bacterium divides every half hour, and all live, how many will there be at the end of twenty-four hours? (Solve by arithmetic or by algebra.) Why does an apple with a broken skin decay more rapidly than one in which the skin is not broken? Why should one not put ice into water to cool it?

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CHAPTER XXIV

FUNGI — PLANTS THAT LACK CHLOROPHYLL

273. Fungi. — The Fungi are of importance to us because: (1) some can be used as food (the so-called mushrooms); (2) one of them, the yeast plant, is used in making bread, beer, and wine; (3) others spoil our food, as when they grow on bread and cake; (4) they cause many diseases in plants.

Fungi differ from most other plants in two respects. They are colorless, or nearly so, chiefly because they have

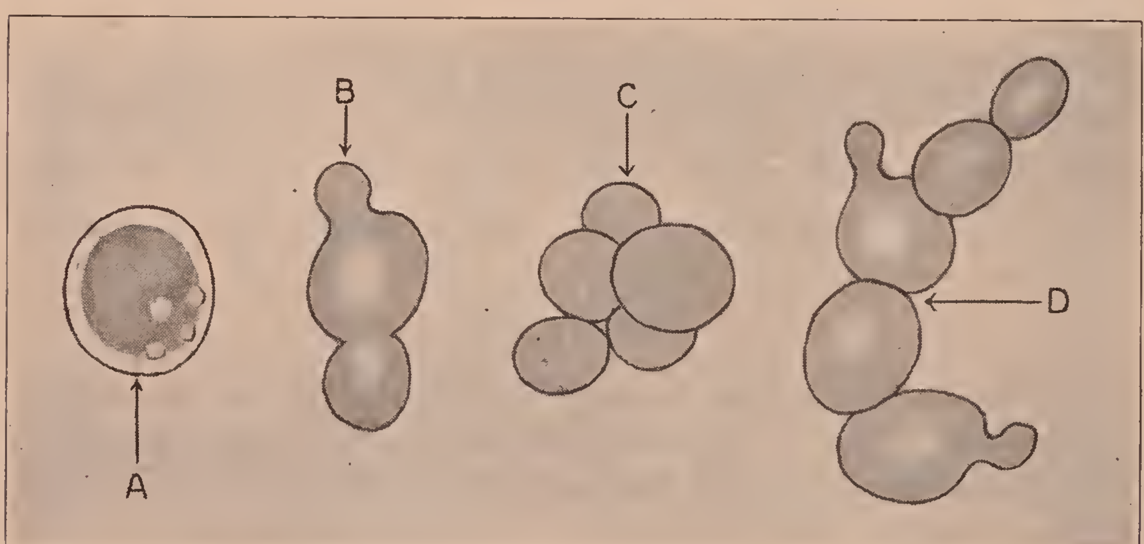

FIGURE 290. — YEAST PLANTS.
A, single cell; *B*, cell with buds; *C*, group of cells; *D*, chain of cells.

no chlorophyll. They are dependent for food on plant or animal substances, either dead or alive, because they lack chlorophyll and hence cannot make their own foods as the green plants do.

Fungi which live on the substances or juices of live plants or of animals are called *parasites* (Greek, *para*, beside; *sitos*,

food); and those that live on dead plants or animals are called *saprophytes* (Greek, *sapros*, rotten; *phyto*, plant).

274. The Yeast Plant. — This plant is a unicellular fungus, too small to be seen by the naked eye. It is oval or almost round in shape, and nearly colorless. It has all the parts of a typical cell, although the nucleus cannot be seen without a special stain. Because it lives upon dead vegetable matter, it is a saprophyte.

FIGURE 291. — FERMENTATION TUBES.

The bulb is filled with nutritive liquid containing yeast plants. As they grow they form carbon dioxide gas which collects in the bulb, forcing the liquid into the upright arm. These tubes are used in estimating the number of yeast plants in a substance and the rapidity of their growth. In water analysis, the formation of gas with certain media indicates pollution.

The Work of the Yeast Plant. — In the making of bread, we know that: (1) yeast secretes an enzyme which breaks up sugar into simpler substances; (2) in this process alcohol is formed and carbon dioxide is set free; (3) the yeast lives on the proteid substances in the flour; (4) both the gas which makes bread light and the alcohol are driven off by the heat of the oven when the bread is baked.

Use is made of the enzymes and yeast in the making of beer, ale, and porter. Before the action of bacteria and yeast were understood, much trouble was experienced in getting uniform products, owing to the presence of undesirable bacteria and yeasts. The possibility of making pure cultures, the use of the microscope, as well as the tests which are made in the laboratories at every step of the manufacture, have placed the industries of bread-making and brewing on a scientific basis.

275. Reproduction of the Yeast Plant. — The method of reproduction of the yeast plant is similar to that of the bacterium, but differs from it in that instead of dividing exactly in two, a bud usually pushes out from the side of the mature plant. Sometimes the second plant will form

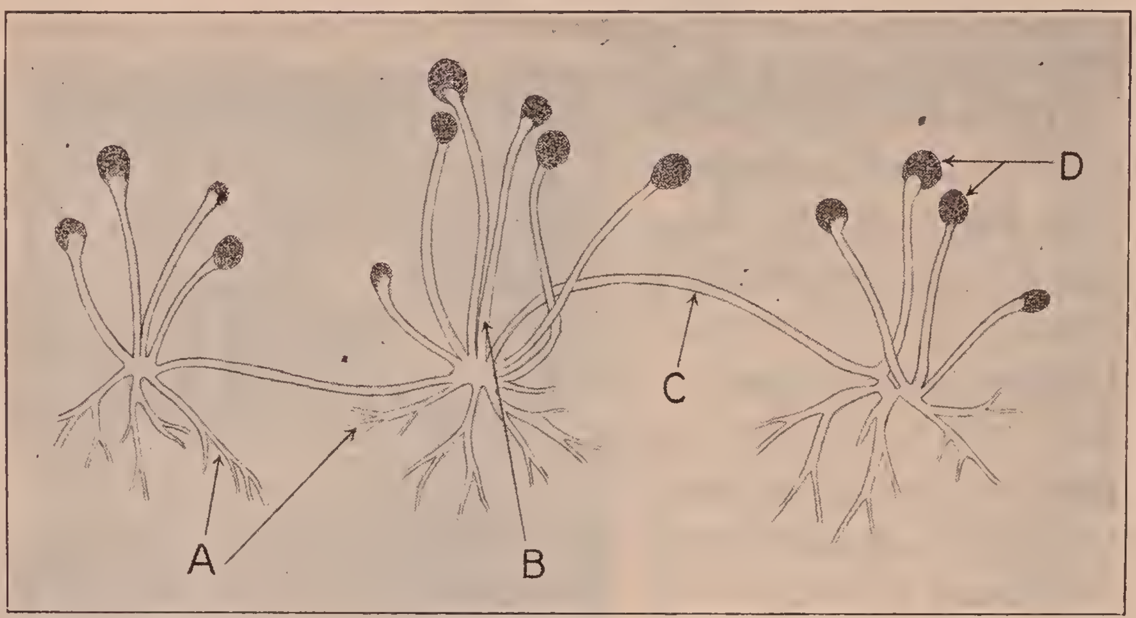

FIGURE 292. — BREAD MOLD.
A, rhizoids; *B*, sporophores; *C*, stolon; *D*, sporangia.

a bud before it breaks away from the first, and so a chain is made. Often a single plant puts forth more than one bud (Figure 290).

LABORATORY STUDY

Prepare a Pasteur solution, a good food for yeast, as follows:

Potassium phosphate	10 parts
Calcium phosphate	1 part
Magnesium sulphate	50 parts
Ammonium tartrate	50 parts
Cane sugar	750 parts

Sufficient water to make a total of 5000 parts. (This may be used for the culture of other molds than yeast and also for bacteria.)

Yeast. — Examine yeast cells under low power. Note their glistening appearance and their number. Under the high power try to find all parts of a typical cell. Label and draw. Look for budding cells and chains of cells. Draw. Make a thick paste of water, yeast, and flour.

Put an equal amount into each of three tumblers. Place one tumbler in a cool place. Into one of the remaining tumblers stir a teaspoonful of sugar and set both in a warm place. Examine several times a day and write down all the differences you observe in the three mixtures. Try to give a reason for everything you observe.

276. Bread Mold. — When examined with the naked eye, bread mold appears like a thick mass of felt, made up of colorless, closely interwoven threads. These threads are called *hyphæ* (hī′fē: Greek, *hyphe*, web) and are of two kinds, one lying on the surface of the bread or just below it, and the other standing upright above the surface. The first are the nutritive hyphæ, and the second the reproductive. On the ends of the latter are round black bodies which are full of spores, each of which is capable of producing a new mold plant, if it falls into a place where conditions are favorable for growth, — that is, where it has plenty of food, the right degree of warmth, and sufficient moisture. Other kinds of fungi may usually be found on a loaf of bread after a day or two, as spores of many kinds of molds are floating in the air at all times (Figure 292).

FIGURE 293. — SHAGGY-MANE (COPRINUS COMATUS) IN PERFECT CONDITION FOR PICKING. (From Murrill's "Edible and Poisonous Mushrooms.")

277. Other Fungi. — A common fungus is the one that kills flies in the fall. At that time a dead fly is often observed on a window or mirror, the body surrounded by a whitish ring. Such a fly has been killed by fungus hyphæ which have filled the body. The ring is composed of spores

thrown off from the ends of the hyphæ which have burst through thin places between the segments of the fly's body.

Other common fungi are potato blight, red rust of wheat, corn smut, which produces the black mass found in an ear of corn, and the bracket fungi, which grow in large numbers

FIGURE 294. — OYSTER MUSHROOM.
An edible mushroom which grows on wood. (From Murrill's "Edible and Poisonous Mushrooms.")

on the trunks of trees and whose hyphæ cause the death of the tree.

The fungi used for food are nourishing, but there is a prejudice against their use because other fungi which resemble them closely are poisonous. As a matter of fact, it is an easy task to learn to distinguish the edible from the poisonous fungi. While the harmless fungi are now used as food much more than formerly, only a few varieties are raised for trade purposes (Figures 294 and 295).

FIGURE 295. — COMMON FIELD PUFFBALL.
This is in condition for picking when the inside is white. (From Murrill's "Edible and Poisonous Mushrooms.")

LABORATORY STUDY

Wet a piece of bread, put a tumbler over it, and set it in a warm place for three or four days. Examine without the microscope to get the general appearance. With the microscope note (1) the clear, colorless threads (hyphæ) making up the mass; (2) the groups of spore-bearing bodies, black and round, on the ends of the upright stalks; (3) the spores coming out of them.

278. Lichens. — Lichens (lī′kĕns) are grayish green plants which look like scales. They grow on old fences, rocks, trees, and the like and are especially noticeable after a rain. A lichen is made up of the hyphæ of a fungus, which inclose the cells of an alga. The algal cells in a flat lichen are usually near the top and bottom, and the fungus is in the middle of the plant. The alga uses the moisture which the fungus collects and brings to the plant, and, by the use of its chlorophyll, makes food, a part of which is used by the fungus. The latter, after it has become accustomed to the alga, cannot live apart from it, and the alga, while it can live by itself, appears plump and prosperous when it is found surrounded by fungal threads. The partnership, therefore, seems to be helpful to both plants. Such a relation between organisms is known as *symbiosis*

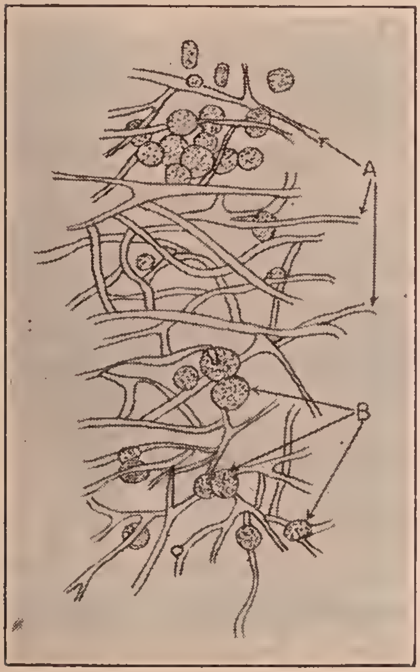

FIGURE 296. — BIT OF LICHEN, ENLARGED.
A, fungal threads; *B*, unicellular algæ.

(sĭm-bī-ō′sĭs, life together: Greek, *syn*, with; *bios*, life) (Figure 294).

Lichens are interesting chiefly as representing this peculiar interdependence of plants. They have little or no economic importance, although in the Arctic Regions they furnish a supply of food for the reindeer. The dye litmus is obtained from a lichen.

FIGURE 297. — LICHENS.

We close the study of the simplest plants with the fungi. As in the case of the bacteria, men have spent their lives studying the fungi, especially those which cause disease. Much has been accomplished, but a great deal remains to be done in finding out the cure for certain fungus diseases, especially those that attack vegetables which we use for food.

FIELD TRIP FOR THE STUDY OF LICHENS

After a rainy period, examine trees, rocks, old fences, posts, and similar places for lichens. Note the form; the color; the kinds of trees having the greatest number of lichens; the trees having the smallest number, and the side of the tree having the greatest number. Make the same examination during a dry period.

SUMMARY

Fungi are plants similar in structure to the algæ, but they lack chlorophyll. On this account fungi cannot make their own food, but always have to use that prepared by

another organism. As they lack chlorophyll, fungi cannot use carbon dioxide, and as a result that which they produce by respiration is cast off into the air, as is the case with animals and with green plants placed in the dark.

The fungi which are most important economically are the yeasts used in making bread, or beer and other fermented liquors; the edible mushrooms; those that spoil food, as bread mold, and those which cause plant diseases, such as corn smut and wheat rust. Fungi reproduce by means of spores. The mutually helpful relation in which fungi and algæ live in the lichen is called symbiosis.

QUESTIONS

What is the color of fungi? Are they ever green? Why not? How does their food differ from that of green plants? How does the yeast plant produce changes in flour? How does the work of bread mold and yeast compare with that of a green flowering plant? What are lichens? Do lichens grow equally well on all sides of a tree? on all trees? How do they appear when wet? when dry? What colors do you find among them?

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Trouessart, Microbes, Ferments, and Molds.

CHAPTER XXV

MOSSES AND THEIR ALLIES

279. General Features. — The plants in this group have more parts, stems, leaves, etc., than the fungi and algæ have; the chlorophyll is evenly distributed, and they tend to grow erect. The life history of the mosses is more complex than that of the simple algæ (Figure 299).

FIGURE 298. — TYPES OF MOSS.
A, calyptra; *B*, capsule; *C*, seta; *D*, female gametophyte.

If a cushion of moss is examined, it is found to be made up of small plants packed closely together. At certain times of the year some of these plants have a stiff, wiry, brownish stalk, surmounted by a boxlike capsule, on top of which may be a shaggy cap or cover (Figures 298 and 299).

280. Habitat. — Mosses grow in moist places, for their rootlike rhizoids are not sufficiently developed to gather water from the soil. They thrive best in shady woods, on decaying logs, and on stones wet by spray. Another reason for their need of moisture will appear in the study of their reproduction.

281. Life History. — If a dry moss capsule is shaken, powdery spores, much like the "smoke" from a puffball, float off in the air. When these spores fall on moist ground, each sends out a small, alga-like thread which branches,

forming a tangled mass called the *protonema* (prō-tō-nē′mȧ: Greek, *protos*, first; *nema*, thread). These threads produce buds from which leafy moss plants grow. The latter produce gametes (reproductive cells which unite to form a new organism) and so these moss plants are called *gametophytes* (gamete plants).

The gametes are of two kinds, eggs (large non-motile cells) and sperms (motile cells). The egg cells are produced in special vase-shaped organs called *archegonia* (ar-kē-gō′ni-a), and the sperm cells in other organs called *antheridia*. When moss plants are reproducing, both of the reproductive organs are found surrounded by sterile hairs at the top of the stems. Some mosses have both antheridia and archegonia on the same plant, while other mosses have only one kind on each plant. The moss plant which bears the antheridia remains short and has on the top a rosette of leaves, in the center of which is the sex organ. The plant which bears archegonia usually grows tall after the egg cells have been fertilized.

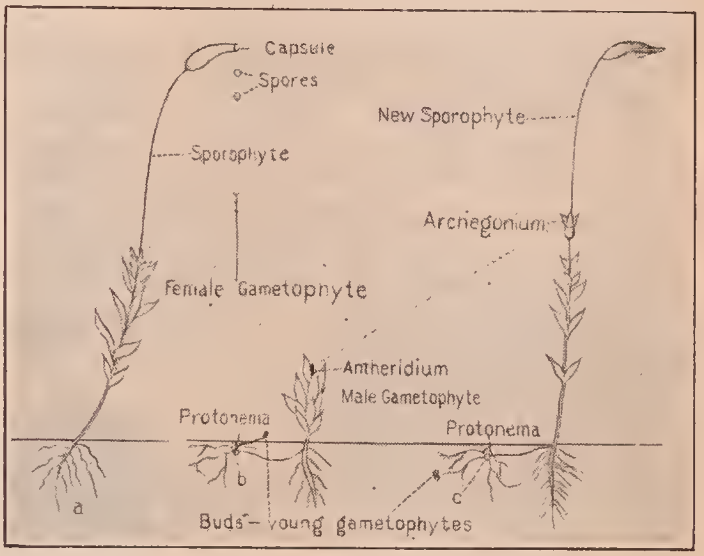

FIGURE 299. — DIAGRAM OF LIFE HISTORY OF MOSS.

Many sperms come from each of the antheridia. These move by the use of cilia when water is present, a film of dew being sufficient. The female moss plant has on its upper end one or more archegonia, each of which contains an egg cell. When the egg is ripe or ready to be fertilized, sperms may swim to it if water is present. A sperm enters the archegonium and fuses with the egg cell, thus forming a sexual cell, known as the fertilized egg cell.

From this fertilized egg cell a sporophyte (spore plant) grows out of the archegonium. The sporophyte consists of a foot, a pad by which it gets its food from the gametophyte, the seta, a slender stalk, and the capsule or spore-case. While every mature gametophyte leads an independent existence, the sporophyte is a parasite.

Thus in its life history the moss plant has two distinct generations, the gametophyte or sexual and the sporophyte which reproduces asexually (Figure 299), by spores. This is known as the *alternation of generations.* That is, a sexual generation produces an asexual generation and an asexual in turn produces a sexual generation.

282. Economic Value. — Mosses have little economic value. In cold regions some kinds are dug from under the snow to be used as food for the reindeer. They are interesting as showing a stage of development of the flowering plants.

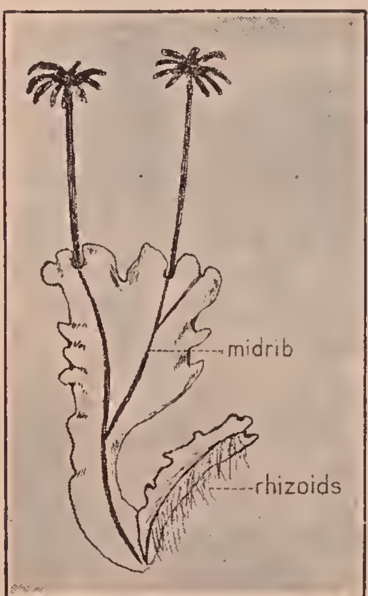

FIGURE 300. — MARCHANTIA.
Plant with archegonial branches.

LABORATORY STUDY

Moss (Polytrichum). Study moss plants and note the difference in size between the male and female plants. Make a drawing to show the difference in size and in the arrangement of the leaves. Select a female gametophyte which has a sporophyte. Draw and label the *seia* or stalk, and the *capsule,* the box at the top. Look for moss plants on trees, along the edges of sidewalks, and on damp soil. With the microscope examine *archegonia* and *antheridia.* Draw and label. When antheridia from fresh material are used, the sperms can usually be seen escaping from the antheridium.

283. Marchantia. — Marchantia (mär-kăn′tia) is a plant belonging to the moss group, which grows in very moist places. It has a thin, broad body or *thallus* (thăl′lŭs: Greek, *thallos,* a young shoot), which is green on the upper surface and

brown or gray on the under side. In the middle of the thallus is a midrib. On the upper surface are diamond-shaped markings, each of which has an opening which leads to an air chamber below. On the under side are rhizoids, which attach the plant loosely to the soil.

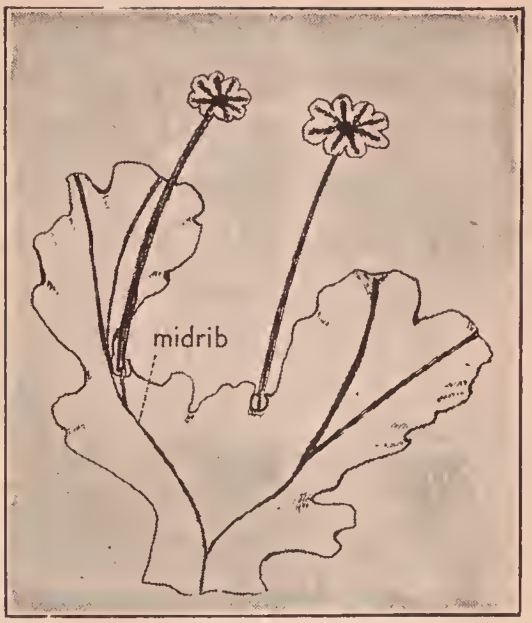

FIGURE 301. — MARCHANTIA. Plant with antheridial branches.

The liverworts, which are well represented by marchantia, are adapting themselves to a life on land, but they are still dependent upon water. Their reproductive habits are like those of the mosses (Figures 300 and 301), but the sporophyte generation is less conspicuous.

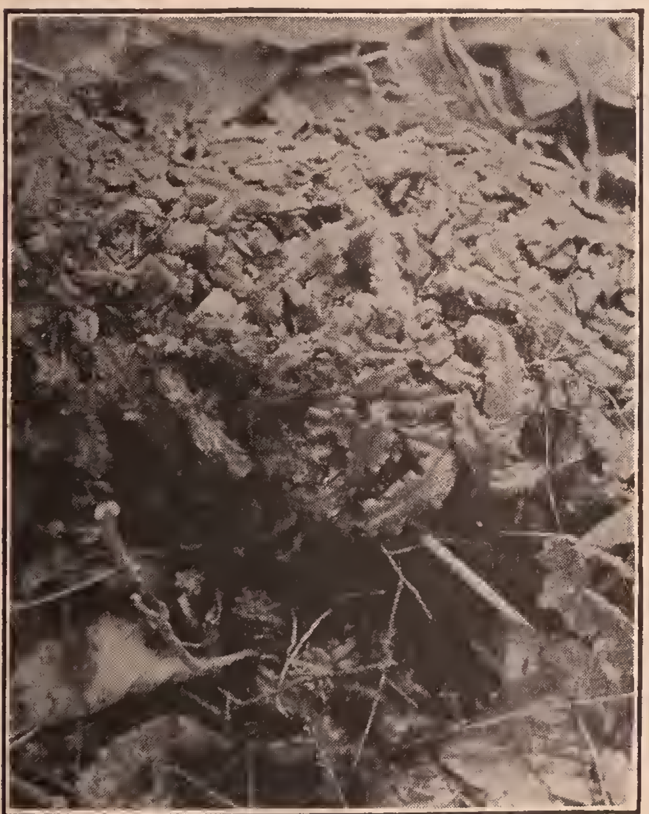

FIGURE 302. — A COMMON LIVERWORT.

LABORATORY STUDY OF MARCHANTIA

Examine pieces of the plant and identify the thallus, midrib, rhizoids and markings. Examine the umbrella-shaped, upright branches which bear the antheridia or male reproductive organs, the branches with slender projections which bear the archegonia or female reproductive organs. With a microscope examine a cross section of the thallus, and observe the openings and air chambers.

SUMMARY

Mosses are much more complex than algæ and

fungi. Specialization is shown in the cells which gather and conduct water, the beginning of the absorptive and conductive systems of plants. There is also the beginning of a system for getting oxygen. The life history of a moss represents the alternation of generations, a generation which reproduces by spore (asexually), and one which reproduces by egg and sperm (sexually). The generation which bears spores is the sporophyte, and that which bears eggs and sperms, the gametophyte.

QUESTIONS

In what respects are mosses more highly developed than algæ, fungi, and lichens? Why do mosses require so much moisture? Give the life history of a moss.

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CHAPTER XXVI

FERNS AND THEIR ALLIES

284. The Group. — The ferns are the best-known members of this group, but club mosses and rushes (horsetails) also belong to the fern family. The study of coal mines has shown us that ferns are very old plants and that they were formerly much more numerous than at the present time. The plants of this group have real stems, roots, and leaves, and most of them are larger than the mosses. While the ferns are not so dependent upon water as the mosses, they grow best in cool, moist woods and in rich soil.

Figure 303. — Forked Veins of Fern Leaf.

285. A Typical Fern. — The fern named pteris or bracken (Figure 305) is one of the best known and most widely distributed. The stem proper is underground and lives on from year to year, while the part above earth renews itself annually. Some of these stems reach a length of ten or fifteen feet. They branch out and give off many fine roots. Leaves, termed *fronds*, form from the upper surface of the stem and grow up through the soil into the air.

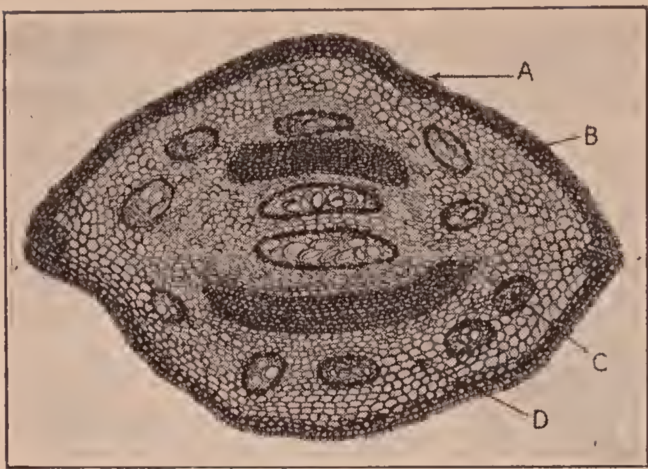

FIGURE 304. — CROSS SECTION OF STEM OF PTERIS.

A, epidermis; *B*, mechanical tissue; *C*, conductive tissue; *D*, fundamental tissue.

The stem of the pteris fern is composed of well-defined clusters of cells which are grouped into tissues. These tissues are: (1) the epidermal on the outside, which protect the stem; (2) the fundamental, which make up the body of the stem and carry on most of the vital processes; (3) the mechanical tissues, variously grouped, which by means of their thick-walled cells give the stem firmness; and (4) the conducting tissue, which is made up of several different kinds of cells, all of which carry liquids (Figure 304). The conducting tissue extends into the leaves and is the vein of the leaf. During certain seasons of the year, lines form along the margin of the under surfaces of the leaves. These lines are made up of many minute reproductive bodies, the *sporangia* (spōr-ăn′jĭ-a: Greek, *spore*, seed; *angeion*, vessel). Each sporangium contains numerous spores. In some ferns the sporangia occur in dots, the *sori* (singular, *sorus;* Greek, *soros*, heap). (See Figures 306 and 307.)

FIGURE 305. — PTERIS, A COMMON FERN.

286. Life History of the Fern. — The fern plant just described forms spores in the sporangia. These spores fall to the ground

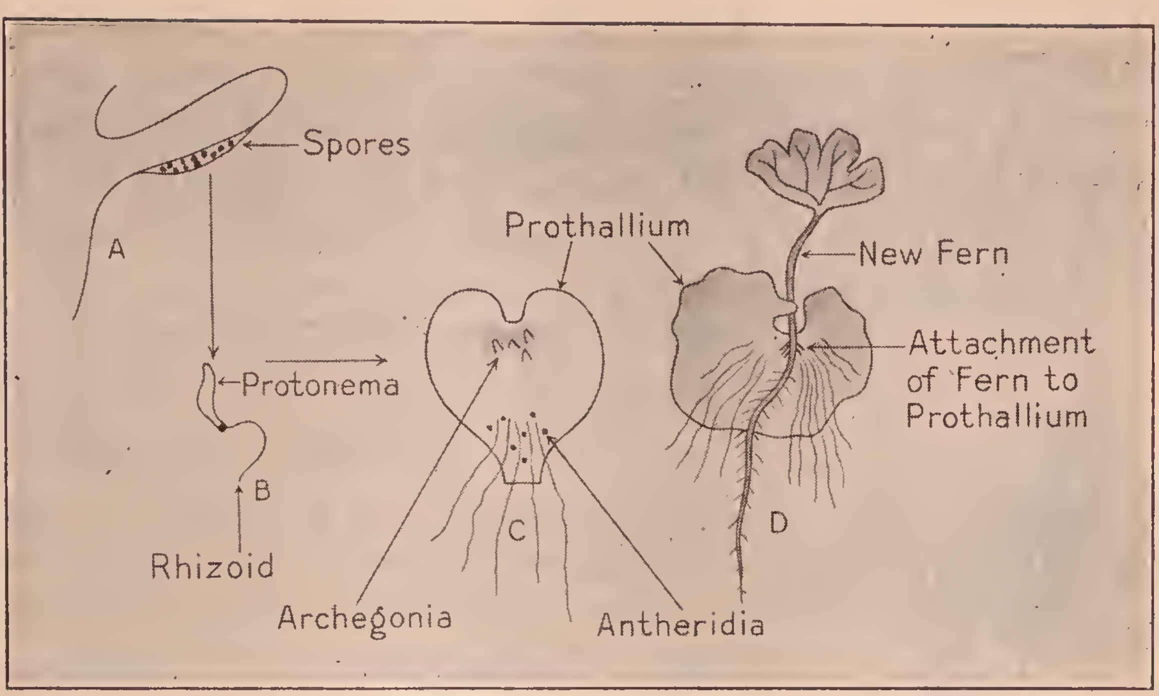

FIGURE 306. — DIAGRAM OF LIFE HISTORY OF FERN.

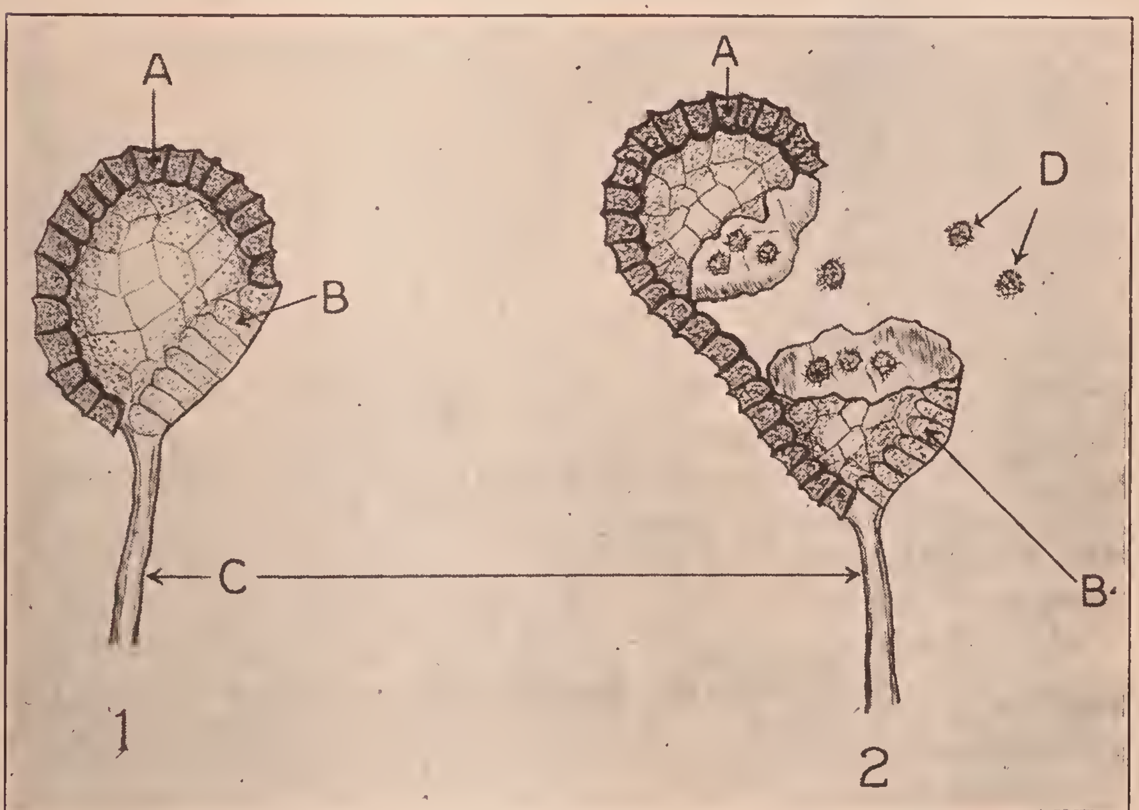

FIGURE 307. — SPORANGIA OF FERN.

A, incomplete ring of elastic cells; *B*, region of thin cells; *C*, stalk of sporangium; *D*, spores.

and soon begin to grow. The sprout from the spore is in the form of a single thread which is a protonema. From the fern protonema there develops a small, flat, heart-shaped body called the *prothallium* (Greek, *pro*, before; *thallos*, twig) which is indispensable to the life of the fern. On the under surface of the prothallium grow small bodies, the antheridia and archegonia. The antheridia produce numerous motile sperm cells, and each archegonium a single egg cell. A sperm cell, swimming about on the surface of a protonema when it is wet, is attracted to an archegonium by a substance which is formed on it. This it enters, fuses with the egg cell, and forms the fertilized egg cell. Prothallium is the name of the fern gametophyte. (See section 281.)

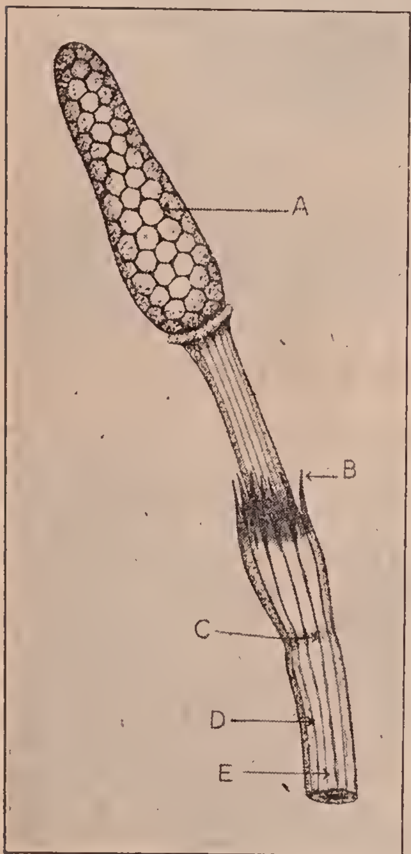

FIGURE 308. — EQUISETUM, FERTILE STALK.

A, sporangial cone; *B*, collar of teeth; *C*, node; *D*, furrow; *E*, ridge.

When an egg cell is fertilized, it begins to divide and a new fern plant is soon formed. The young plant remains attached to the prothallium and gains nourishment from it. As soon as the young fern is able to get nourishment by its own roots, it begins life as an independent plant and the prothallium dies. There is the same alternation of generations in the fern that occurs in the mosses, the prothallium being the gametophyte and the "fern" the sporophyte, but the latter is the longer lived and much the larger plant (Figure 305). The prothallium is so small, in fact, that it is seldom noticed, while in the life history of mosses the green, leafy gametophyte is larger than the sporophyte and lives longer.

FIELD TRIP TO GREENHOUSE OR WOODS TO STUDY FERNS

Note the color of the plants, the characteristic fern leaf with its stipe or central stalk, its pinnæ or leaflets, and also the method of unrolling from the base to the tip. Note the fruiting dots (sori) on the back of the leaves. In what kind of soil are ferns found? Do they grow best in the sun or in the shade? Do leaves remain green during the winter? Note the underground stem and its roots. Look for buds and young leaves. Note the forked veins.

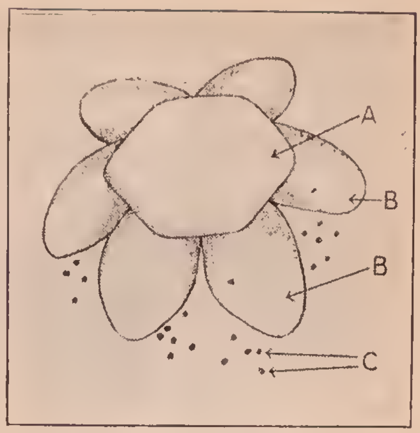

FIGURE 309. — SPOROPHYLL OF EQUISETUM (enlarged). *A*, sporophyll; *B*, sporangia; *C*, spores.

LABORATORY STUDY

Examine the cross section of a stem and note the different kinds of tissue. Draw and label: (1) *epidermal tissue* on the outside; (2) *mechanical*, dark brown tissue in masses near the center; (3) *conductive tissue*, large openings; (4) *fundamental tissue* filling the rest of the space. With a microscope examine the epidermis on the under side of the leaf, noting the shape of the cells and the stomata. Pull off a bit of the epidermis and try to distinguish the green guard cells. Examine a sorus with low power of the microscope and see how it is made up of sporangia on stalks.

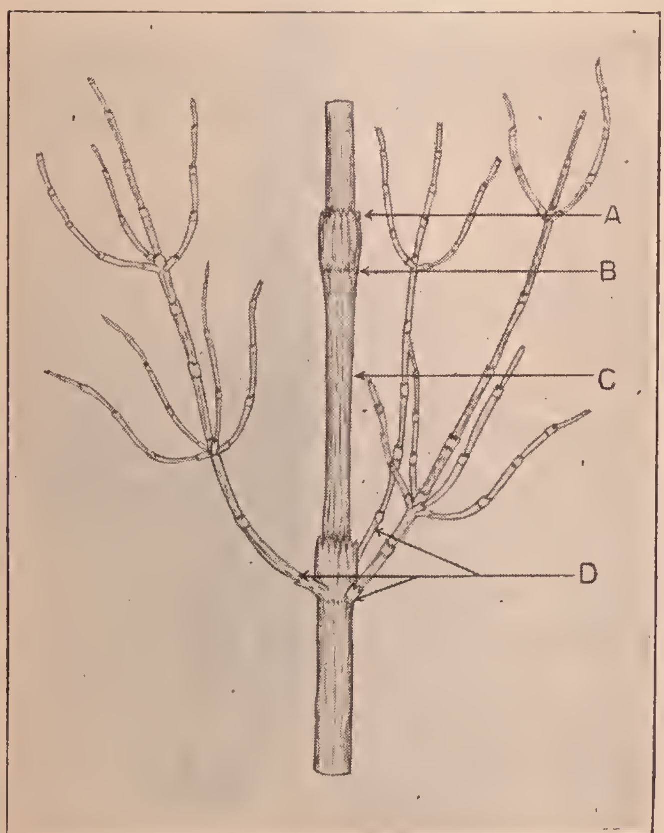

FIGURE 310. — EQUISETUM. *A*, collar of teeth; *B*, node; *C*, internode; *D*, branch.

287. Related Forms. — Club mosses, horsetails, and selaginella (sē-lăj-ĭn-ĕl′lȧ) are plants which belong to the fern group. Club mosses bear their spores in a spike on scales which are modified

leaves. In appearance these plants are more like mosses than ferns (Figures 312 and 313).

Horsetail, or equisetum, grows in waste or damp places. It has a hollow stem, with joints, a mineral coating on the outside of the stem, and

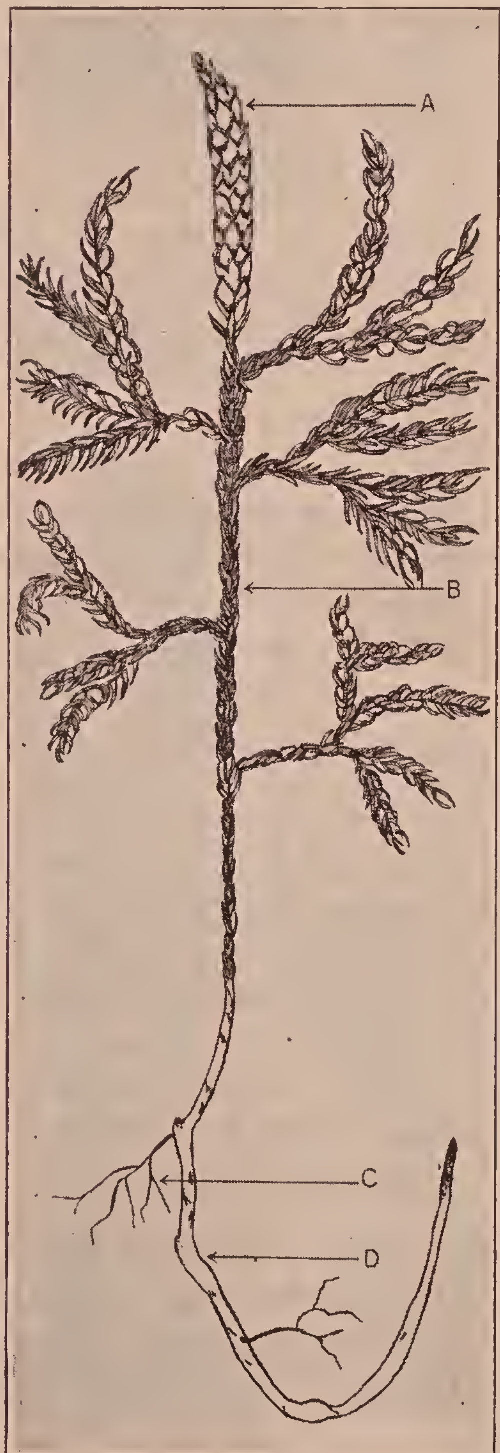

FIGURE 311. — CLUB MOSS.

A, sporangial cone; *B*, aërial stem; *C*, roots; *D*, underground stem.

FIGURE 312. — EQUISETUM OR HORSETAIL, STERILE BRANCH.

branches in a circle around each joint. The conductive tissue in this plant is arranged near the center of the stem (Figure 315).

Selaginella is seldom seen in northern latitudes, except in greenhouses.

288. Economic Importance. — The fern group, like the mosses, have little economic importance. The spores of the club mosses are used in making certain kinds of fireworks (especially those used indoors); also in drug stores to keep pills from sticking together. The plant itself is used in Christmas decoration. Horsetail, so named from its appearance, is a common plant in waste places. Another plant in this group was formerly cut, tied in bundles large enough to be held easily, and used for scouring woodwork or tinware, which accounts for its other name, the "scouring rush."

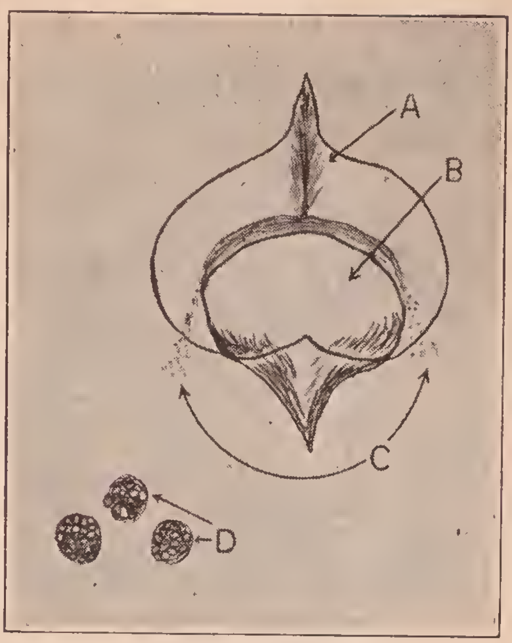

FIGURE 313.— SPOROPHYLL (enlarged).

A, sporophyll; *B*, sporangium; *C*, spores; *D*, spores (enlarged).

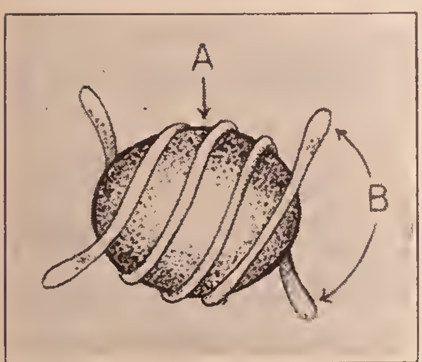

FIGURE 314.

A, spore equisetum; *B*, elators.

289. The Formation of Coal and Peat. — Ages ago ferns were more numerous than they are now and many of them grew to be as large as our present trees. Geologists tell us that the climate was warmer and more moist than it is now, and conditions especially favored the growth of fern plants. Where these large ferns died and fell to the ground, great masses accumulated.

As the earth's surface changed, these masses became covered with soil or water, and under the influence of heat and pressure they, together with other plants (gymnosperms),

changed into coal. At the same time natural gas and petroleum, or rock oil, were formed. No coal is being formed at the present time, and when our supply is exhausted we shall have to find other sources of heat and power.

Peat, found in old bogs, consists largely of vegetable matter. When dried it can be used as fuel.

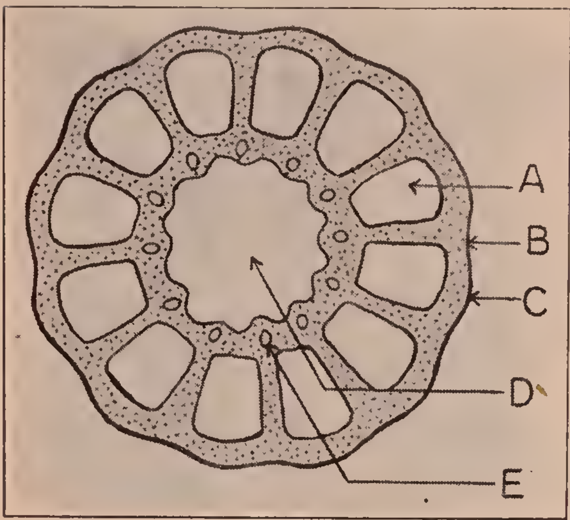

FIGURE 315. — CROSS SECTION OF STEM OF EQUISETUM.

A, air passage; *B*, furrow; *C*, ridge; *D*, central air passage; *E*, vascular bundles.

SUMMARY

Ferns and their allies are less dependent on water than are the algæ, fungi, and mosses. They are more highly organized, as they have epidermis, stomata, mechanical tissue, conductive tissue, stem, roots, and leaves. Their life history shows the alternation of generations, consisting of spore, protonema, prothallium, and sporophyte. Club mosses, horsetail, and selaginella are closely related forms. Coal was formed from ferns which grew to the size of trees in regions which were then hot and moist.

QUESTIONS

What parts of the flowering plant are found in the fern? In an animal what corresponds to epidermal tissue? to conductive tissue? to fundamental tissue? to mechanical tissue? Compare the life history of a moss and a fern. Why can ferns do with less water than mosses? Illustrate by diagrams or sketches the life history of a fern. What plants are related to ferns? Tell how coal beds were formed.

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CHAPTER XXVII

THE CONIFERS (GYMNOSPERMS) — FORESTS

290. General Characteristics. — In passing from the ferns to the conifers, usually known as evergreens, we go from a lower to a higher order of plants. None of the algæ, fungi, mosses, or ferns bear seeds, but all reproduce by spores or by fertilized eggs. Most of the evergreens are seed-bearing trees which vary in size, but which are alike in having trunks that taper from the base to tip without dividing. Such trunks are called *excurrent,* while the trunk of the elm which divides repeatedly is called *deliquescent.* (See Figure 316.) The conifer group contains the largest plants in the world and those which live to the greatest age. Their foliage is usually composed of dark green, needle-like leaves which remain attached to the tree for two or three years. Thus the trees always have some foliage and so are termed "evergreen."

291. Pine Tree. — The pine illustrates the plants of this family. The pine has all the parts of a flowering plant — stem (trunk), branches, roots, leaves, seed-producing organs, and fruit (cones).

Stem. — The trunk does not divide, — a marked characteristic of conifers. In a forest where trees are crowded together and there is in consequence a struggle to get light, the trunks grow tall and most of the branches are near the top.

A cross section of a stem shows a series of rings, known as annual rings, by which the approximate age of the tree can be told. In the spring when all the conditions are at their best and growth is rapid, the cells of the tree are

large and thin-walled, strength being sacrificed to size. In the fall or during a dry time in summer, the cells formed are much smaller and the walls thicker. These small cells which show most plainly make up the annual ring. During a season in which long, dry periods occur, more than one ring may be made. From the center to the bark extend lines

FIGURE 316. — CONIFERS.

Note the undivided (excurrent) trunk.

which are made of pith and are known as medullary rays. The part of the stem where increase in thickness takes place is just under the bark.

Branches. — The branches leave the stem almost horizontally and nearly in a circle around the trunk of the tree. In the pine they curve upward, but each kind of evergreen has its own habit of curvature in its branches.

Leaves. — The leaves, called needles, are long, slender, and flattened on one side. They grow in bundles of two, three, four, or five needles, according to the kind of pine. The leaves, which are borne but once in a place, remain on the tree from two to five years and then fall off, leaving the branches bare except near the ends.

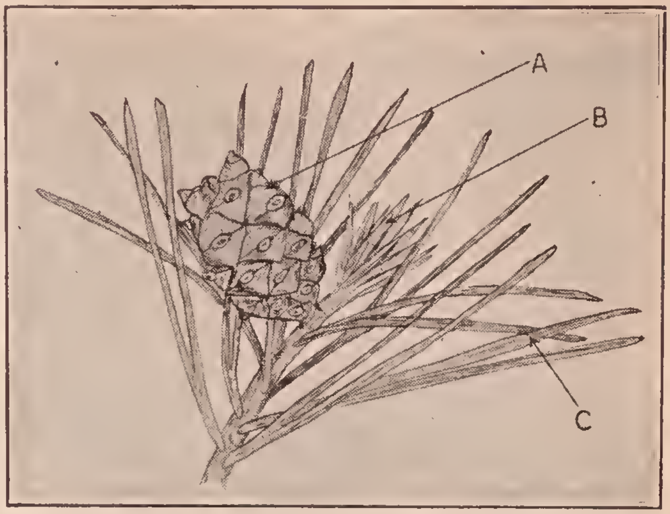

FIGURE 317. — YOUNG FEMALE STROBILUS.
A, strobilus; *B*, new leaves; *C*, leaves of previous year.

Roots. — The roots of the pine vary according to the kind of pine and according to the soil, but they are always extensive.

Seed-producing Organs. — Early in the spring, two kinds of strobili are found on the new shoots which grow from the terminal buds. One kind looks like short catkins, and they are borne in clusters near the base of the shoot. They consist of scales arranged spirally around the central axis. Each scale bears two pollen sacs. These are the *staminate strobili.* They wither soon after shedding their pollen, although they may remain on the tree for a year. The other kind of strobilus is short and thick, and is found at the tip of the shoot or on the side of the shoot near the tip. This is the *female strobilus* or carpellate cone, which like the staminate

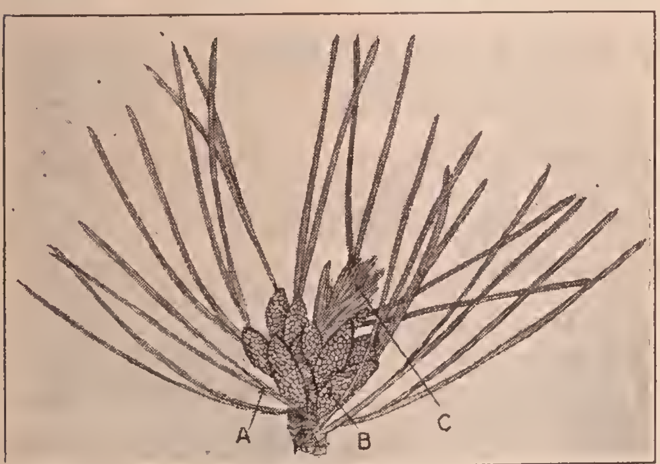

FIGURE 318. — MALE STROBILI.
A, leaves of previous year; *B*, male strobili; *C*, new leaves.

strobilus already described is made up of scales arranged spirally around a central axis. Each scale near its base bears two ovules. When the pollen is ripe, each grain, being provided with wing-like air sacs, is easily blown about by the wind. Some of the pollen sifts into the carpellate cone through the spaces between the scales, which at this time are separated slightly. Then the scales close up, the cones turn downward, and continue to grow for several months (Figures 317–321).

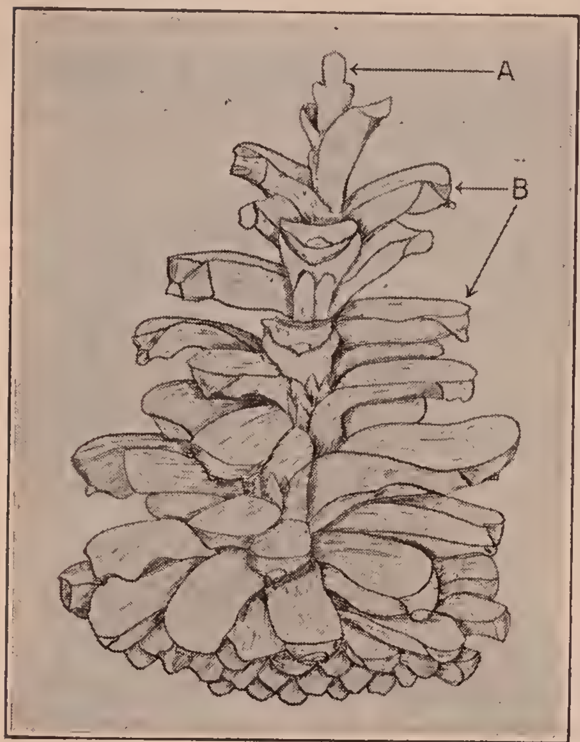

FIGURE 319. — MATURE FEMALE STROBILUS OR CONE.

A, central axis; *B*, scales (sporophylls).

Fruit. — During the next year, the pollen grains which are shut up inside the scales put forth pollen tubes and fertilize the egg cells which develop in the ovules. From the fertilized eggs the embryo pines develop.

When the cones are about two years old the scales open and allow the seeds to drop out. Each seed is provided with a wing by which it is blown about, for the pine depends on the wind to scatter its seeds as well as its pollen. Because the seeds lie on the scale without being inclosed in an ovary, all these plants are called *gymnosperms* (Greek, *gymnos*, naked; *sperma*, seed).

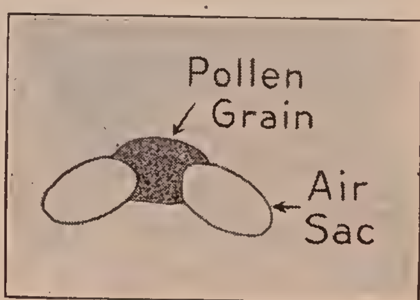

FIGURE 320. — POLLEN GRAIN OF PINE.

292. Habitat. — The evergreens grow in sandy soil in temperate or in cold climates, but a few of them occur where it is very warm. The finest evergreen forests in the world are found

in the western part of North America, on the slopes facing the Pacific Ocean.

293. Related Forms of Conifers. — Hemlocks, spruces, firs, and balsams have smaller, flatter needles than the

FIGURE 321. — OTHER CONES.
a, arbor vitæ; *b*, hemlock.

pines and they are not arranged in bundles. Cedars have scale-like leaves. Larch and cypress trees shed their leaves in the fall, but in other respects are much like the pines.

FIELD STUDY OF GYMNOSPERMS

Most of the work in connection with gymnosperms should be done out of doors. The student should learn to know by sight all the local native evergreens and those commonly planted for ornament. He should note the method of branching and the character of the trunk compared with other trees. He should observe the position of the cones on the branches and be able to give the reasons therefor. In the spring he should look for the male and female strobili, and for leaf buds in the winter. He should examine the leaf scars and the external rings which mark a year's growth, and decide how many years each tree keeps its leaves. He should note the arrangement of the leaves on the branches, the annual rings in the wood and their relation to the grain of the wood, the resin on wounds, the curvature of the branches, and other features readily observed.

STUDENT REPORT

	Needles Single Alternate	Needles Scale-like	Needles in Bundles	Cones Large	Cones Small
Hemlock .					
White Pine					
Larch . .					
Cedar . .					
Spruce . .					
Etc. . . .					

LABORATORY WORK

In the laboratory examine a cross section of the stem to see the difference in the cells grown in the early and in the late part of a season. Note the pith and medullary rays. If specimens are available, examine sections of wood from different trees. Make a collection of the woods found in the vicinity. Examine scales from staminate and carpellate strobili. With the microscope examine pollen of pine. Draw and describe all.

294. Economic Importance. — The value of the gymnosperms can scarcely be overestimated. Most of the trees are sawed into lumber for building purposes, but some of them are used in their natural form for telegraph poles, masts of ships, and timbers of mines. Wood pulp, from which most of our paper is made, is produced from small spruce trees. The by-products of this group of trees are of great value. From the pine come tar, pitch, turpentine, and resin, while the bark of the hemlock was formerly extensively used in tanning leather.

295. Forestry. — By forestry we mean the raising of repeated crops of timber on land unsuited for agriculture. An additional meaning that has come to be attached to it is the proper use of forest crops. This definition will make it plain that it is quite separate from agriculture, which is concerned principally with the crops which feed man or his animals or which furnish him material for clothing. It is

also distinct from lumbering which has to do only with cutting and preparing the trees for market in whatever form they are to be used.

296. The Need for a Study of Forestry. — We are using timber three times as fast as it grows. A study of a few minutes will show many of the uses to which wood is put which accounts for its great consumption. For instance, the paper on which you are writing was probably made from wood; the pencil which you are using is made largely of wood; the table on which you are writing is of wood; the floor on which the table stands is made of wood; the walls of the house, or some part of them, are made of wood; the cars in which the lumber was brought to your city were made of wood; the ties on which the rails rested over which the cars ran were made of wood; the chair in which you are sitting was made of wood. Not only are we dependent on wood for these many articles of daily use, but a system of water works depends for its success on the presence of woods or forests, (1) to insure a plentiful supply of rain, and (2) to hold it back so that it may produce a steady supply during the hot weather when rain does not fall often. Again, the covering

FIGURE 322. — A VIRGIN FOREST OF MIXED HARD WOODS AND CONIFERS IN NORTHERN PENNSYLVANIA.

The splendid trunk in the middle ground is that of a cucumber tree. (Hugh P. Baker.)

of forests prevents the soil from being washed away, which results in two disadvantages, (1) the loss of the richest part of the soil itself, and (2) the stopping up of channels which might be used for transportation. Water thus held back by the porous soil of forests keeps rivers and lakes at a usable level during the whole season instead of having most of the water run off in a flood or freshet during the rainy season, causing destruction as well as wasting the water.

Besides, forests, by acting as wind-breaks, often make a locality much more comfortable to live in, and some persons go so far as to say that the presence of a forest positively affects climate favorably, making a locality cooler in summer and warmer in winter. It is now well agreed that at least one fifth of the territory of a country should be wooded in order not only to have lumber enough to use, but also to secure the other benefits arising from forests, some of which are more important than the direct products of the forests themselves.

297. Extent of Original (Virgin) Forest. — When the settlers came to America, the forest on the eastern coast extended for about a thousand miles inland from the Atlantic, reaching to the treeless prairies of the middle section. On the western coast was a belt even wider extending from the prairies across the Rocky Mountains to the Pacific Ocean.

The forests of the United States now cover about 550,000,000 acres, or more than one fifth of the total area.

"Generally speaking, countries having over twenty per cent of woodlands have forest resources sufficient to supply their lumber industries and their firewood consumption, provided that such area is properly stocked and conserved." — Schenck, *Forest Policy*, page 71.

298. Attitude of the Early Settlers towards Forests. — The first care of the settlers was to provide shelter from wild beasts and from the hostile Indians, and their second care was to secure a supply of food to last over the winter. To

accomplish both of these, the destruction of trees was necessary. Trees furnished the most abundant and the most natural material of which to build houses and to make

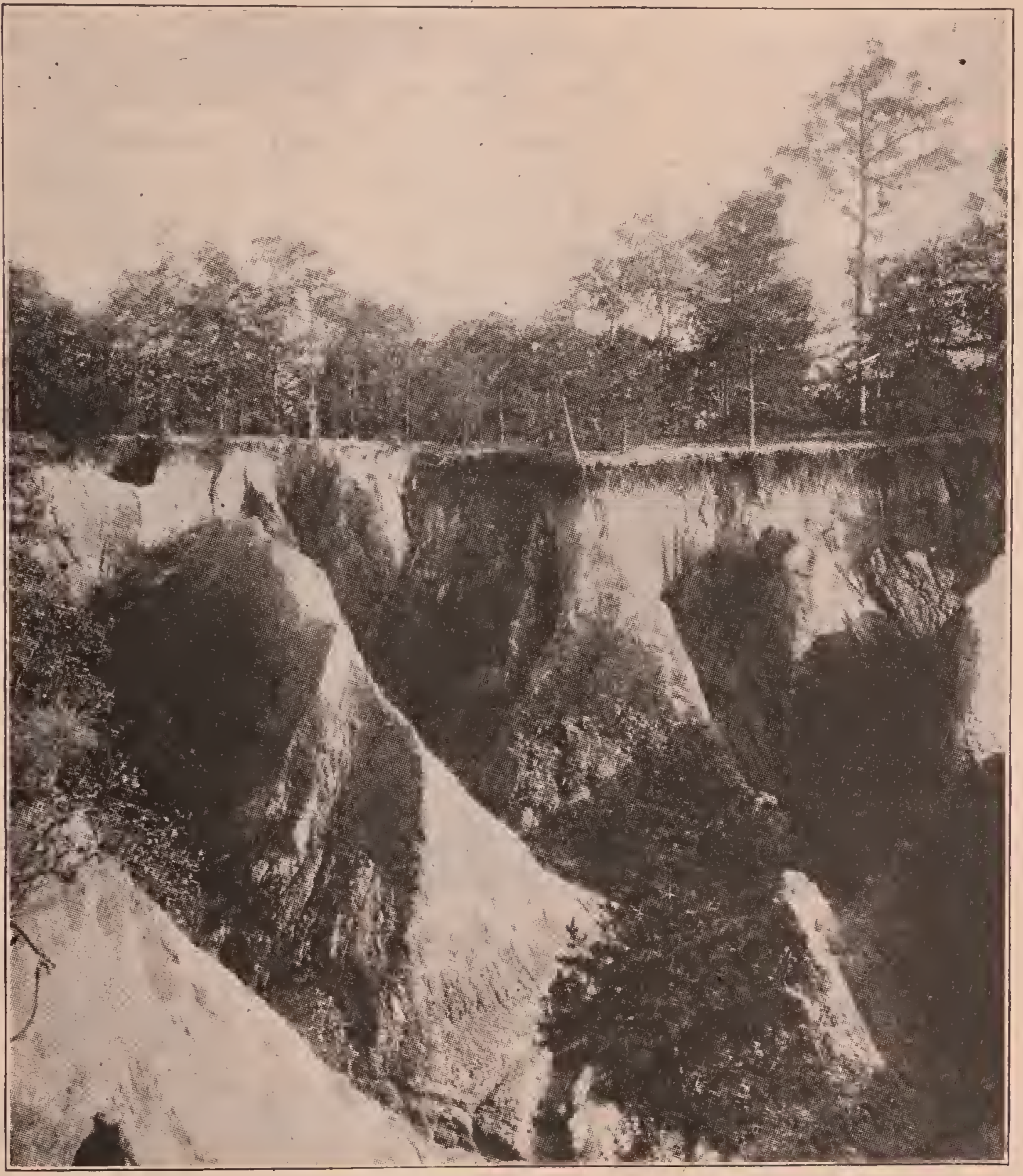

FIGURE 323. — WHAT DEFORESTING IS DOING IN THE UNITED STATES.
A scene in North Carolina showing the rapid removal of soil after the forest is cut.

fuel, and they had to be removed before crops could be planted. Furthermore, they sheltered the settlers' enemies, so it was a matter of safety to have extensive clearings around

the houses. Besides, trees were so plentiful that there was no need to be careful about using them in any way. This attitude has been so thoughtlessly maintained that large tracts have been cleared for immediate profit or pleasure without thought of the future. Now the time has come when forests have to be conserved and additions made

FIGURE 324. — WHAT DEFORESTING DID IN CHINA.
This represents the appearance of 200 square miles of once wooded mountains, which a century ago paid rich revenue on their lumber products.

to them so far as possible, a condition which will become even more marked as the population increases and as the needs for wood and lumber become greater. Conservation does not mean locking up the products of forests to prevent their being used, but seeing that they are properly used and providing for a future supply. Conservation has become necessary on account of previous extravagance. Formerly, when a settler had cleared the land so far from his house that it was a trouble to bring in wood, it was not a

difficult matter to move to a new locality where there was still plenty of timber near at hand.

299. Why the Forests Are Beneficial to the Soil. — We have already seen (page 256) that for the roots of a plant to be able to get their food from the soil it must be of such a nature that the roots can easily make their way through it, and it must be able to hold water between periods of rain. Trees help in this way, that when their leaves decay they form a part of the soil called humus, its most valuable part so far as furnishing the plants with food material is concerned. The decayed leaves have the property of making the soil capable of absorbing moisture and holding it as a sponge does. Incidentally this prevents floods and freshets, and also prevents the good soil from being washed away, or eroded.

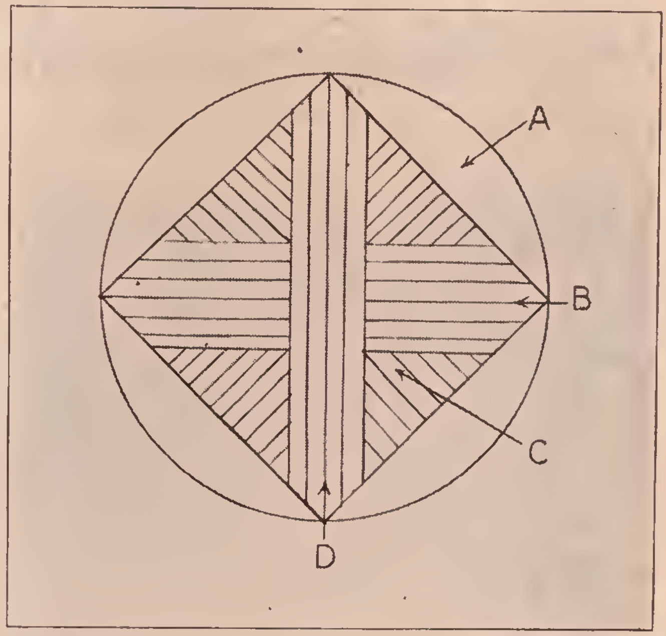

FIGURE 325. — DIAGRAM SHOWING HOW LOGS ARE QUARTER-SAWN.

A, slabs removed to square the log; *B*, *C*, short radial sections; *D*, long radial sections. Note that at least one end of every section is oblique, and that some of the sections are very small, entailing waste. Quarter-sawn lumber is used for furniture and interior finishing.

300. Forest Products. — Enough has been said to give some idea of the value of wood and lumber to the human race. A little thought will add greatly to our appreciation of the uses of forests, some of which are incidental, but none the less valuable. In some localities, for example, maple trees are raised for the sugar and sirup which they produce. Chestnuts, hickories, walnuts, and others give us nuts year after year, as well as lumber when they are cut down. Willow trees give us a superior kind of charcoal used in medi-

cine and in making certain kinds of gunpowder; the poplars and basswood or linden give us excelsior, so useful in packing fragile articles and in making cheap upholstery. Turpentine, obtained from the pine trees, is used in paint and varnish. Thin sheets of the more beautiful kinds of wood are laid over the cheaper or less beautiful kinds in the form of veneer. Wood alcohol, so useful as fuel, is obtained from wood wastes, like sawdust and shavings.

White pine was formerly the kind of pine most in demand as well as the most abundant. Now yellow pine is taking its place on account of the scarcity and high cost of white pine, although yellow pine is slightly inferior. White oak is highly valued for interior finishing, floors, and furniture. Maple has a fine-grained, hard wood which is much prized for furniture and other purposes. Curly maple and bird's-eye maple are valued as wood for veneer. The former has a wavy grain, and the latter has numerous glistening points scattered through it, thought to be undeveloped adventitious buds. Black walnut, cherry, and mahogany are valuable for furniture. Hickory, elm, and ash are used for handles of tools and for parts of vehicles where toughness is required. Applewood, holly, and box are sought for turned articles. Cedar, larch, and cypress are used for posts and poles, and basswood for trunks and crates on account of its toughness, lightness, and elasticity. Poplar and catalpa are planted where shade is desired in a short time, on account of their rapid growth.

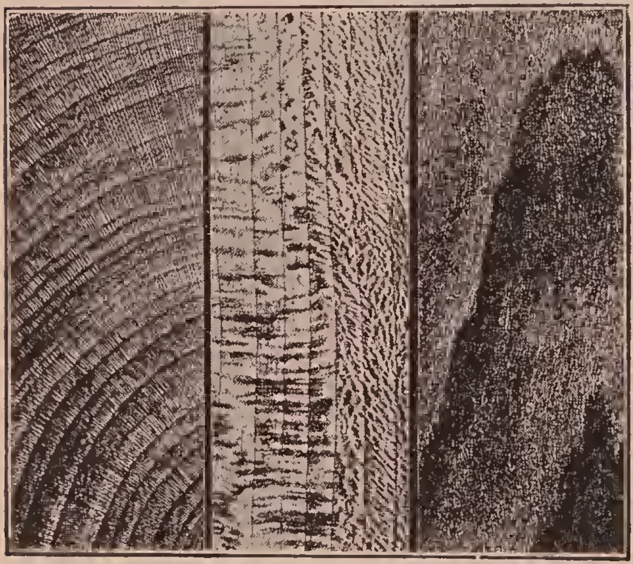

FIGURE 326.— PHOTOGRAPH OF SECTIONS OF WOOD.

The part of a tree nearest the center is called the heart-wood, and that outside of it the sap-wood. Heart-wood is often of a different color from sap-wood, due to substances deposited in the cell-walls when they become old. For many purposes, heart-wood lasts longer than sap-wood, especially in posts or timbers used under ground. Charring the ends of posts put into the ground increases their durability.

301. Preservation of Wood. — There are great differences in woods as to their ability to last in the soil or under water.

FIGURE 327. — NURSERY WHERE YOUNG TREES ARE STARTED.

Some, like cypress, cedar, and locust, have the ability to withstand decay on account of substances contained in the wood, such as resins. All wood lasts longer if it is seasoned, that is, allowed to dry out in the air before being used. Wood that is to be used in damp places, however, usually needs treatment to prevent or at least to retard the process of decay. As decay is caused largely by the work of bacteria or of fungi, both of which depend upon moisture as one of their chief vital conditions, the use of timber thoroughly

dried is one precaution taken to insure its lasting. Other methods used are charring portions that are to be covered by earth, and a third, the most common, is the use of chemicals. Railroad ties, for instance, are thoroughly impregnated with a solution containing creosote, among other substances, by being soaked in it for a long time, or by having it driven in under pressure. This acts as an antiseptic preventing bacteria and fungi from growing in the wood, and prolonging the usefulness of the timber to a remarkable degree. While treating ties in this way is costly at first, it is an

FIGURE 328. — YOUNG PLANTATION IN THE ADIRONDACKS.

economic measure on the whole, as it takes a smaller quantity of timber, and less labor than would be the case if the ties had to be replaced frequently.

Some kinds of wood depend for their beauty on the glistening medullary rays. These show to best advantage when cut lengthwise or obliquely, an effect obtained in quarter-sawn timber.

302. Properties of Wood. — The question may arise, What makes wood so valuable? Is there nothing else that can be used in its place? One of its most valuable properties is that it is so easily shaped with sharp tools. Another is that it is light, compared with iron and steel, at the same time

being tough and elastic. It has remarkable resistance to crushing, twisting, and pulling apart. A piece of yellow pine one inch wide and thick and a foot long bears a load of 720 pounds without breaking, when supported at the ends. It requires a weight of 17,300 pounds to pull it apart, and a load of 7400 pounds to crush it. It is beautiful and it takes a high finish. The beauty of wood depends

FIGURE 329. — YOUNG PLANTATION 16 YEARS AFTER PLANTING.

much on its grain, the closeness of which and the hardness of the wood determining its suitability for particular purposes. For instance, where wood-cuts are to be made, the grain must be very small, and the wood very hard. Holly and box are best for this. In the case of wood used for fork and shovel handles, the qualities desired are toughness and smoothness. These are found in ash and hickory, and so

the list might be lengthened indefinitely. Balsa wood, newly discovered in the tropics, is much lighter than cork. This is employed in making life preservers and rafts to be used in case of accident at sea.

303. What Kinds of Land Shall We Use for Forests? — Generally speaking, that land which is so steep or so inaccessible that it cannot well be used for cultivating crops. This will depend largely on the locality. Conifers usually do better on poor land than do the deciduous trees.

FIGURE 330. — FOREST FIRE IN MONTANA.

If the land is poor, planting any kind of trees will improve the quality of the soil. There are 10,000,000 acres of land in New York State unsuitable for agriculture, yet capable of growing beautiful and profitable forests.

304. How Can Tracts Be Reforested? — The state will coöperate when large tracts are to be reforested. There are three ways, the use of any one of which depends on local conditions. Seeds may be gathered and sown broadcast, but this is expensive and wasteful, as most of the seed is lost by

falling on spots where it cannot grow, or is eaten by squirrels and birds. Again, it is not evenly distributed, and to obtain an even set requires additional work in transplanting. Better results are obtained the second way, namely, by planting the seeds evenly and covering them to reduce the number that may be wasted. This is nearly as costly, and not so satisfactory as the third method, which consists of

FIGURE 331. — THE RESULT OF HURRICANE AND FIRE IN IDAHO.

planting the seeds and raising the young plants in nurseries till they are old enough to live in the open. Then they are set out under favorable conditions, in large numbers, and allowed to grow with only such care as disease or injury makes necessary.

305. Protection of Forests. — Young forests, and old ones too, have their enemies. Fire, set by lightning or careless smokers or campers, fungal diseases, made possible by acci-

dents or careless pruning, and insect enemies, require that forests have supervision and attention to prevent damage and consequent loss to the owners. The persons who watch over forests in this way are called forest rangers.

306. The Work of a Forest Ranger. — A forest ranger has numerous duties, chief among which are to look out for fires and to report them when they occur. As a prevention, campers and others are cautioned to be careful about letting fire spread, stations or lookouts are maintained from which a large territory can be surveyed for signs of fire, airplanes are also used to this end, telephone lines are kept in repair to provide for calling help to fight fire, roads are cut for the same purpose, and also with a view of making it possible to check the spread of fire by removing all brush and other material which will burn. When fire occurs, it is fought by clearing paths across which it cannot travel for lack of fuel, and by digging trenches, which have the same effect. In some cases fires are beaten out with damp cloths or with branches of trees, and in rare cases, by the use of water. In some states regular trains are maintained on which are huge tanks containing water, and apparatus for throwing it some distance from the track. Prevention has proved

FIGURE 332. — CASTLE PEAK FIRE LOOKOUT. What is the advantage of this location? From a National Forest in Colorado.

more effective than any kind of device, however, and most efforts are being made in that direction. Signs and posters warn persons to be careful.

Campers are taught how to select a spot for a fire, how to care for it to prevent its being a menace, and how to put it out when breaking camp.

Of the forest fires in the United States during 1917, 7814 in number, 2132 were caused by lightning, and the others

FIGURE 333. — SIGN CONTAINING WARNING ABOUT FIRES.

by human means, nearly all preventable; 952 were incendiary; 1288 were caused by careless campers; and 1003 by sparks from railroad locomotives, in violation of laws which call for spark arresters on engines used in or near the forests.

Forest rangers also keep watch of the trees to see that fungus does not cause the death of trees, and to prevent the spread of such diseases when they are found. In localities where cleared spaces in the national forests are rented for grazing purposes, forest rangers see that the regulations concerning the grazing of cattle are observed, collect fees,

and otherwise serve as government agents. In some localities, the tract must be regularly patrolled to prevent the theft of valuable timber.

FIGURE 334. — POSTER WARNING AGAINST FIRE.

The life of a forest ranger requires good health and a love for the out-of-doors. It requires, too, at least a common school education with special training to enable the ranger

to recognize fungal diseases, and to estimate the quantity of timber on a tract or the lumber in a tree.

Scientific forestry is now practiced on about 90% of the public forests of the United States and on about 2% of the woodlands privately owned. Only about one fifth of the wooded area of the United States is under government control. New York State is taking steps to preserve her

FIGURE 335. — FIRE TRAIN IN THE ADIRONDACKS.

forests and also to reforest large tracts which have been cut over (Figures 327–329).

National Forest Reserves are maintained in 23 states, chiefly in the western third of the United States. In the eastern portion many of the states have preserves, and in addition there are a few privately owned preserves.

307. Qualification of a Forester. — In addition to the preparation and qualifications necessary for a position as forest ranger, a forester must have much broader technical knowledge. This is usually gained by taking a course in a

college of forestry, and by practical work in the forests under supervision.

Forestry has long been practiced in Europe, but it is a new enterprise in the United States. As the necessity for it is seen and as more and more forest preserves are made, openings will occur as foresters for greater numbers of young men.

FIGURE 336. — FIRE SLASH.
The scene of a great destructive fire in 1908.

There are two methods of obtaining revenue from forests, one known as clear cutting, in which all the timber is removed and the land cleared, after which it is again planted with young trees. This method has two advantages, one, that the timber is all about the same size, and the other that no trees need to be injured in removing some. Selective cutting, the second method, has this advantage, that the forest can be made to produce revenue continuously, but

it has the disadvantage that in removing large trees, smaller ones are likely to be maimed or mutilated. Much depends upon the locality and the kinds of trees planted as to which kind of cutting is better. In both of these methods the forester is of great service.

308. Lumbering. — This includes, primarily, cutting the trees, and getting them to the sawmill. Great waste has been characteristic of unscientific lumbering. This waste assumed two forms, injuring young trees in felling mature ones, and making use only of the most valuable part of the trees felled. The latter practice not only wastes much wood, that might be used in many ways, but it is also a menace to neighboring forests to have the dead, dry tops and limbs lying about to afford fuel for fire. When lumbering is done scientifically, injured young trees are pruned and treated so that they may not become diseased by the entrance of spores of wood-destroying fungi, and all parts of the trees felled are either made use of, or the less valuable are piled and burned under conditions which do not menace the safety of the remaining trees and which leave a clean floor, one of the best possible protections against forest fires.

309. Lumber. — Lumber includes all the forms of wood secured by sawing the trunk of a tree lengthwise. The log is first squared by taking a slab, that is, the bark and the rounding part of the trunk beneath it from each side of the trunk. This is then sawed lengthwise, the shape and size of the sections determining the name as well as the uses to which the various pieces are put. So we have beams, planks, joists, lath, boards, etc.

Lumber as it comes from the saw is termed *rough lumber*, being used chiefly for parts of buildings that are to be covered. Dressed lumber is prepared by smoothing the surface of rough lumber. The kind of tools used and the degree of smoothness produced depend on the use to be made of the lumber.

310. Shade Trees. — When one has occasion to plant a tree, the question often arises as to what is the best kind of tree to plant. While much depends on where the tree is to be planted, and on the care it will receive afterwards, there are a few general rules that may be kept in mind. For instance, elm trees, poplar trees, and silver maple trees have the bad habit of clogging waste and sewer pipes in their search for water, of which they demand a large supply. Besides, one should consider that silver maple trees are brittle and apt to split when they become old, and that their shade is light. Elm trees in some localities are subject to the attacks of elm beetles and require spraying to preserve them. Poplar trees are hard to kill when it becomes necessary to remove them, owing to their habit of sending up sprouts from the roots and from the stump. Horse-chestnut and catalpa trees make a great deal of litter, detracting from their usefulness as ornamental trees. Other trees, like the Norway maple, have the habit of branching so low that they require frequent trimming in cities, to prevent their being in the way of umbrellas. The trimming is likely to mar their symmetry. Hard maple, oak, sycamore, ash, linden, and tulip are satisfactory trees for most localities, having all the good features and none of the bad ones of the other trees mentioned. It should be remembered in planting trees along paved streets that the conditions are very hard, and they should have special care, otherwise they will die from much cutting of the roots and branches, from the attacks of insects, and from the lack of food and water. In planting, trees should have space enough left between them so that each tree may grow on all sides.

When it becomes necessary to trim a tree, care should be taken to saw the limbs off as close to the trunk as possible, and to cover the fresh wood with a coat of paint. This close cutting will enable the wound to heal readily, and the application of paint will exclude bacteria and fungi

which might otherwise gain entrance to the interior of the tree and cause injury or death.

SUMMARY

The conifers belong to a class of the higher plants. They have periods of active and less active growth, both together resulting in the appearance of annual rings. Because their seeds are not entirely inclosed in an ovary, but lie uncovered on a scale, they are called gymnosperms. Conifers are of great economic importance, for they supply much of our lumber, tar, pitch, and all our turpentine and resin. Forests help to regulate the flow of streams and they prevent the washing away of the soil.

QUESTIONS

How are gymnosperms like other plants? How do they differ from other plants? What kind of trunk is characteristic of gymnosperms? How does a tree which grows in a forest differ from one which grows in an open field? Why? What are annual rings? How are they formed? Describe the branches; the leaves; the roots; the strobili; the fruit. What is a sporophyte? Name the gymnosperms. Make a list of the uses to which lumber is put. What other products come from the evergreen forests? In what ways are forests beneficial? What are the governments doing to protect them? What regions in your own state are covered with forests?

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CHAPTER XXVIII

PECULIARITIES OF PLANT LIFE

311. Unusual Plants. — In order to live, all plants must have conditions favorable to their vital processes, and many of them develop special modifications which aid them in the struggle for existence. Some of the modifications already studied in this book are the arrangement of leaves or the length of petioles to secure air and light; the presence of color, odor, and nectar, devices to attract insects and thus secure the pollination of flowers; and the use of wings, pappus, and hooks to secure the distribution of seeds. Many of the carnivorous (Figures 337, 338, 339) and parasitic plants are remarkable for the modifications which make it possible for them to obtain nitrogen, an element lacking in the food supply of their particular environment.

FIGURE 337. — LEAVES OF PITCHER PLANT.

The Pitcher Plant. — The leaves of this plant form a sort of vase which retains water in the bottom. When insects crawl into the leaf, their escape is prevented by hairs which grow around the opening on the inside and point downward, and the unfortunate victim, exhausted by his struggles to get out, falls into the water and is drowned. When the bodies decay, the plants secure the nitrogen which they are unable to get through their roots.

The Sundew. — This plant has round leaves covered with long glandular hairs which secrete a sticky substance. When an insect alights on a leaf, the hairs bend over and hold the victim until it dies, the secretions of the plant meanwhile digesting the soft parts of the insect. When the leaf has absorbed this digested food, the hairs release the remaining parts, which then fall off, while the hairs resume their usual position.

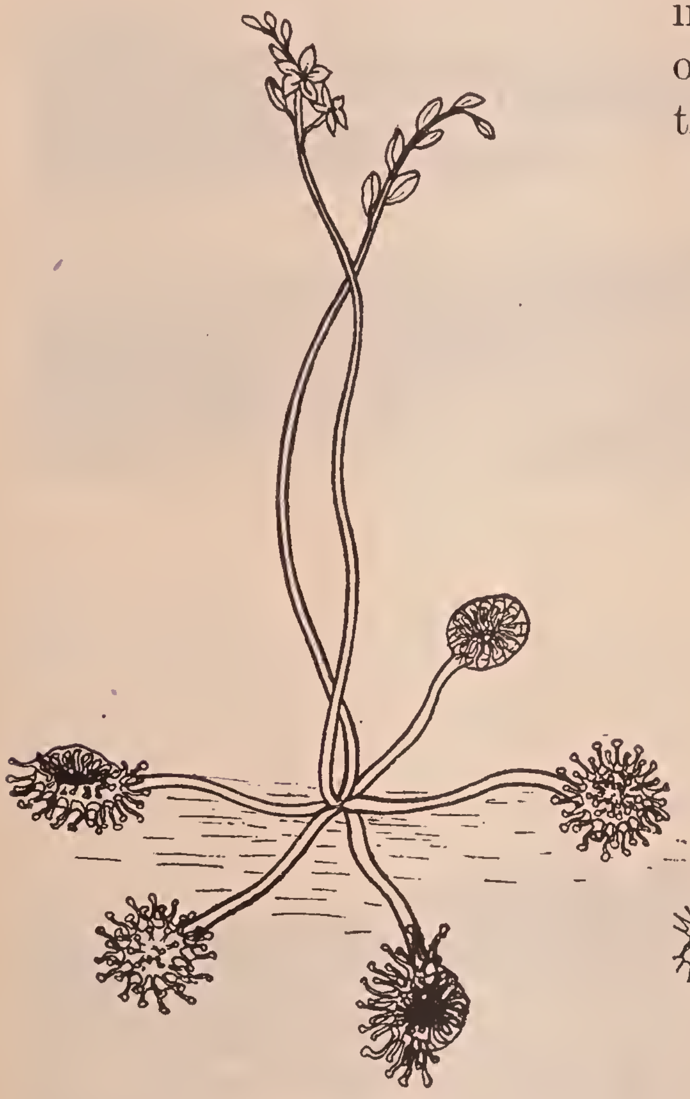

FIGURE 338. — DIAGRAM OF SUNDEW.

FIGURE 339. — VENUS'S FLYTRAP.

Venus's Flytrap. — This plant has another way to catch insects. The leaves end in a trap-like device in two parts which lie flat like the leaves of a book (see Figure 339). When an insect alights on one side, the other closes quickly and confines it by the interlocking hairs on the edges. Digestion and absorption soon take place, after which the leaves lie flat again, ready for another insect visitor.

FIGURE 340. — CAT-TAILS AND ARROW-HEADS.

FIGURE 341. — WATER-LILIES — HYDROPHYTES.

Indian Pipe. — This plant, although it produces flowers and seeds, has no chlorophyll and so is a waxy white in appearance. It gets its nourishment from decayed organic matter, usually wood, just below the soil. A fungus which grows on the roots helps them to absorb this prepared food (see Figure 268).

Mistletoe. — We are most familiar with this plant as a part of our Christmas decorations. Mistletoe has chlorophyll and so is able to manufacture its own food, but it has no roots for absorbing water, making it dependent on a larger plant for this necessary part of its vital conditions. The plant possesses absorbing organs which pierce the bark of the trees upon which it grows. As a result it does much injury to the trees by using the water which they need for their own life processes. In the South the mistletoe is regarded as a great pest.

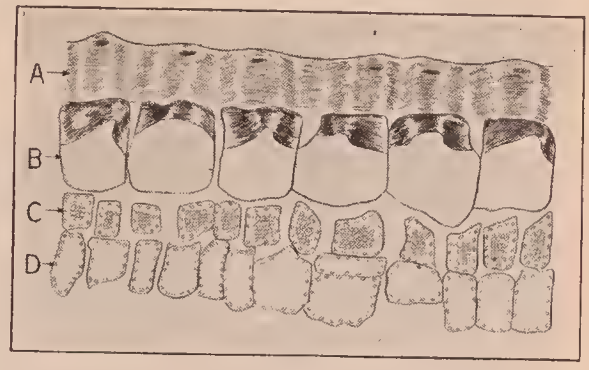

FIGURE 342. — CROSS SECTION OF LEAF OF DESERT PLANT.

Note the very thick layer of cutin (*A*); the epidermal cells, also cutinized (*B*); the short, incomplete layer of palisade cells (*C*); and a few cells of the spongy layer (*D*). Compare with Figure 263.

312. Movements of Plants. — Most plants move slowly and only in response to one of several stimuli. Touch, or contact, is the stimulus in the case of sundew and Venus's flytrap, both of which are peculiar in moving quickly. Tendrils curve under the influence of the same stimulus, but they move slowly.

313. Plant Societies. — The term *plant society* is applied to any collection of plants which grow under similar conditions. The trees of the forests, and the grass and weeds of our lawns, are typical examples. In most cases water, or the lack of it, is the basis for classifying or grouping plants in societies. Some plants, *e.g.*, many algæ, live submerged

in the water, while others, like the waterlilies, live partly in the water, lifting their leaves and flowers into the air.

Plants which live in the water are called *hydrophytes* (hy′drō-fītes: Greek, *hydor*, water; *phyton*, plant). If such plants have roots, they are little more than holdfasts, for the hydrophytes do not need organs of absorption. Most of the members of this plant society are without mechanical tissue, for the water holds them firmly on all sides. The algæ lack a conducting system as well, for

FIGURE 343. — SAGE BRUSH — XEROPHYTES.

their source of food is all about them. Waterlilies get their oxygen and much of their carbon dioxide from the air through their leaves, which float on the surface of the water with the stomata on top. Air passages in the long, slender stems convey air to the roots which lie in the mud. Hydrophytes which lie under water have their leaves finely divided to offer as much surface as possible to the water and thus secure a full supply of oxygen.

Plants which live in desert regions, of necessity, have to live on little water. They are called *xerophytes* (zĕr′ō-fītes:

Greek, *xeros*, dry; *phyton*, plant). Xerophytes usually have long roots so that when moisture is present they may gather it rapidly. Many forms have little surface exposed to the air; the branches are few, and there are no leaves. The stem, which is green in color, performs the work of photosynthesis. To conserve their water supply further, the xerophytes have a thick epidermis and few stomata (see

FIGURE 344. — GIANT CACTI — XEROPHYTES.

Figure 342). These plants are an admirable illustration of making the most of what one has.

Desert plants live in regions where it is usually both hot and dry, but plants of the Arctic Regions have many of the same modifications, only in a lesser degree. Much of the time severe cold prevents the roots from absorbing water, and the plant must keep what it already possesses. Some of the Arctic plants, therefore, have leaves which roll to reduce the surface and have, in addition, a coating of hairs, both devices for retarding transpiration.

Most of the plants which we see and which live where there are no great extremes of heat or cold and where it is neither wet nor dry are called *mesophytes* (mĕz′ō-fītes: Greek, *mesos*, middle; *phyton*, plant). They have few

FIGURE 345. — ORCHID.

This plant lives in bogs. A habitat intermediate between that shown in Figures 340, 341, and 362.

characteristics in common, but all have roots suited to the soil in which they grow, and leaves which in shape and arrangement serve the purposes of each plant better than any others would do. Examples of this are the narrow,

upright leaves of the grass, which grows thickly crowded together, the broad leaves of the trees, and the leaves of the ivy, which grows on walls, arranged like a mosaic. Many divisions of the mesophytes might be made, for some prefer sunny locations, others shady places, and so on.

Plants which live in the air make up another group, called *epiphytes* (ĕp′ĭ-fītes: Greek, *epi*, upon; *phyton*, a plant) because they usually attach themselves to the stem of a larger plant. Their modifications consist of one kind

FIGURE 346. — LONG-SPURRED VIOLET, A MESOPHYTE.

of roots for fixing them to their support and another capable of absorbing and storing water. The latter organs are called *velamens* and are composed of spongy tissue. They are situated on the outside of the plant, their work being to soak up rain and dew and conduct it to an inner region where it is used as the plant needs it. Velamens can also absorb moisture from the air. The epiphytes are characteristic of the tropics, where the air is full of moisture and where rains fall frequently. In our own part of the world, lichens have somewhat the same habit, and orchids in greenhouses are another example.

The study of plants which deals with their distribution and the factors which govern it is called *plant ecology* (ĕ-kŏl′ō-jy̆: Greek, *oikos*, home; *logos*, talk).

FIGURE 347. — MISTLETOE.
A semi-parasite. This tree has no leaves.

314. Plant Succession. — When a swamp is drained, a forest cleared, or a desert irrigated, plant conditions are changed. Thus it becomes impossible for some plants to

thrive in their former habitat, and possible for others to grow where before they could not. The replacing of one plant society by another is termed *plant succession.* When a forest is cleared and the tract burned over, the plant called fireweed appears in large numbers, even if a cultivated crop is planted. After a year or two the fireweed gives way to a growth of blackberry and raspberry bushes, which are later replaced by grasses and weeds of various kinds.

Another example of plant succession is seen in regions covered by fresh lava from a volcano. At first nothing grows. Probably bacteria and fungi appear before other plants are noticed, but lichens are usually the first to be observed. These die and decompose, and their remains, together with bits of lava loosened by frost, wind, or water, accumulate in depressions and form a soil in which mosses can grow. The remains of the mosses add to the organic matter in the slowly increasing soil, and, in the course of time, ferns and larger plants can grow. The last finally replace the mosses as they replaced the lichens.

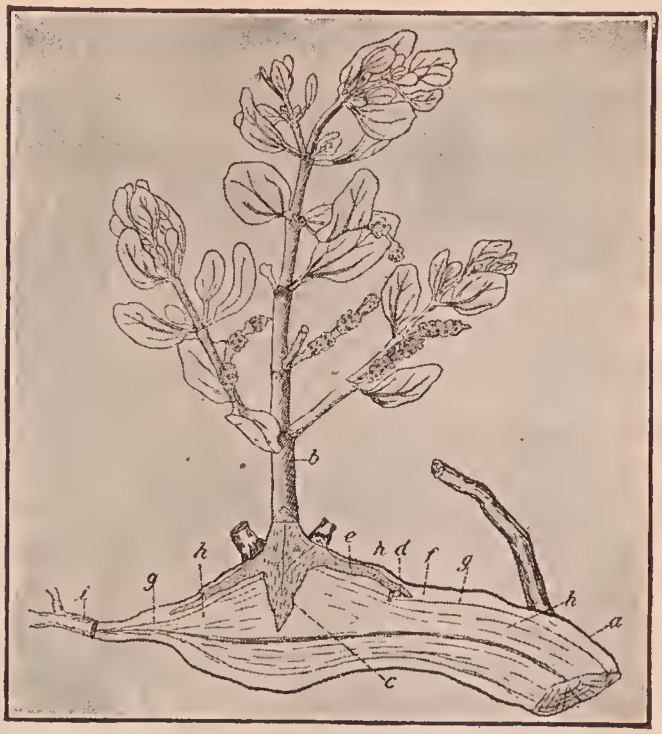

FIGURE 348. — DIAGRAM.

Sectional view of a branch infected with mistletoe, showing the relation between the parasite and host; *a*, branch of host tree; *b*, mistletoe; *c*, primary sinker; *d*, sinker from cortical root; *e*, *f*, cortex of soft bark; *g*, cambium or growth ring; *h*, wood of branch. The starving and dwarfing of the branch beyond the mistletoe is shown at *i*.

315. Summary of Our Interest in Plants. — Our first interest in plants is economic, that is, we think of them

first in terms of their usefulness or harmfulness to us. As every animal in the world is dependent directly or indirectly upon plants for food, it becomes obvious to what a degree we are benefited by the ability of plants to make food out of the air and the soil.

Man could live comfortably on what three plant families furnish, — the grasses, which include all the cereal foods and sugar; the pulse family, which furnishes most of our vegetable nitrogen; and the rose family, which includes the plants which furnish us our luxuries in the way of fruits. In eating animal products, man is still dependent upon the grass family to furnish food for the cattle from which he obtains meat, milk, cheese, and butter. For clothes, man depends indirectly upon plants for the leather and wool of the domestic animals, and directly for cotton and linen. Plants are the source of many of the materials out of which houses are made and furnished.

Some plants (bacteria) cause disease, while still others provide remedies with which to cure diseases. Plants please our eyes as we travel about. They keep up the supply of oxygen in the air; they rid the air of the carbon dioxide which we have cast off; they provide employment for millions of men who raise food plants, manufacture them into food, and distribute them throughout the world; and they employ other millions in the production of cotton plants and cotton cloth for our clothing.

The farmer who raises plants has an interest in knowing what kind of soil and climate, how much water, air, and light each kind of plant needs to yield him the best results. To this end he has to know something about the habits of plants in general, and about their enemies and their diseases. He has learned by experience that some plants grow better when planted in hills; others in drills, and still others sown broadcast. He is still trying to find the best kind of plant food for each plant, and the method of

cultivation which best enables plants to get their full supply of food and moisture, and he is still fighting weeds which deprive the useful plants of their share of food, water, and light. Yet he is conscious, if he stops to consider, that he cannot make a plant grow. His part is to create good vital conditions.

We are interested in the work of men who are trying by cross-pollination, grafting, and selection to reduce the

FIGURE 349. — TROPICAL VEGETATION.
Note how different the plants are from ours.

undesirable parts of plants and to increase their capacity for food, storage, or whatever we find desirable. Experiment stations maintained by the United States Department of Agriculture and by individual states are making many experiments in this field, especially in increasing the number of fruits on trees and in reducing the size of the seeds in berries.

316. Scientific Interest. — In addition to practical interests, that is, besides the supreme importance of plants

to man and his dependence upon them, there is another interest, — that of the scientist in plants as organisms. The scientist studies how plants are like animals; how they differ from them; how each is dependent upon the other for waste products; how plants depend upon animals for the pollination of their flowers and the scattering of their seeds and how the plants make use of the wind and water for the same purposes.

He studies, too, the increasing complexity of plants from the simple, one-celled plants dependent upon water for existence, up through the plants which are becoming accustomed to living on land, and finally to those which have complex systems and complex flowers. He finds that all are related, and the more he learns about them, the more interesting does he find their relationships. He is interested in seeing how the change from water to land calls forth changes in structure to fit the new environment; how in land plants, each one has adapted itself in form, size, arrangement of leaves, and so on, to make the best possible use of the air and water which it is able to procure.

In trying to find the causes of such variations of plants the scientist performs many experiments, often upon the smallest plant, for size and complexity are no indication of the interest which may center in a plant structure. Bacteria, for instance, which are the simplest and smallest of all plants, are being studied more to-day than any of the others.

Every year adds to our knowledge of the nature of plants, their relations to one another and to man. Besides these relations due to their surroundings, plants bear towards one another the relation of dependence and independence, which we have discussed under *parasitism* and *symbiosis*.

Plant life itself remains a mystery. The poet Tennyson has given expression to thoughts of those who have tried in vain to solve the many problems which have arisen in connection with the study of plant life.

"Flower in the crannied wall,
I pick you out of your crannies.
I hold you here, root and all, in my hand,
Little flower, but if I could understand
What you are, root and all, and all in all,
I should know what God and man is."

HOME WORK

To show the response of stems to gravity, place seedlings or young plants in unnatural positions and note their effort to right themselves. To show the response to light, examine a potato from a dark cellar, which has sprouted in the spring; a plant that has been allowed to grow toward the light in a window; the bending of seedlings, and the like. For the storage of food, examine all the common garden vegetables and test them for the food which they contain. If possible, find some vegetables which have been kept for two seasons and have produced seed, and note their appearance after all the food has been used.

Sprout slips of balsam, geranium, and ivy to get adventitious roots. Show such roots on the stem of a tomato plant where it has been allowed to lie on the ground, and on Wandering Jew.

Examine leaves in the laboratory and in the fields to find illustrations of all the terms used. Examine onions and cabbages for example of leaves modified for storage, and the onion also as an example of a reduced stem. Find examples of all the terms used in the discussion of flowers and buds. Make collections of leaves of shade trees.

QUESTIONS

What are the ordinary adaptations of plants? What are the peculiarities of the plants that get their nitrogen from insects? Describe Indian pipe; mistletoe. Discuss the movements of plants. What are the commonest plant societies? Mention the localities in which each is to be found. Name plants characteristic of each. Describe mistletoe and its effect on a tree. What is meant by plant succession? What is our economic interest in plants? What scientific interests have we? What are some of the facts we are trying to find out?

REFERENCES

Bergen and Caldwell, Practical Botany, pages 477–493.
Bessey, College Botany, page 320.
Plant Societies.

CHAPTER XXIX

SOME GENERAL PLANT PROBLEMS

Students of botany had to make a study of plants before they could understand how to keep plants well, how to produce new kinds of plants, and how to solve similar problems. It is more important to-day than ever before that such problems be solved simply because there are more human beings living to-day than at any previous time. In the preceding chapters on parts of plants, you have been making a scientific study which has furnished you with reliable facts about the life of plants. This is the kind of study that all who know about the life of plants have made, and it should make it easier for you to understand the few general plant problems which have been merely outlined in this chapter, because whole books are needed for a complete discussion of them.

317. Plant Diseases. — Three typical plant diseases, Cabbage Yellows, Potato Wart, and Black Stem Rust, have been selected to illustrate how some of the fungi destroy our food plants. As you learn about each of these diseases, you will see that it is much more important that the disease be prevented than cured. Note the kind of knowledge necessary to recognize them and the methods used in treating them. In the case of the rust your attention is called to the complicated life history of this fungus parasite as it lives first on the wheat, then on the wild barberry in a never ending cycle.

The farmer who would be successful must learn how to recognize the common diseases of farm plants. If he does not know about this important part of farming, he can ask

the Agricultural Experiment Station to tell him what he ought to know.

Cabbage Yellows. — This disease is caused by a soil fungus, *Fusarium conglutinans*, which is not known outside of the United States.

Effects. — The fungus attacks the roots of the plant either in the seed bed or soon after transplanting. It works greatest havoc during a hot, dry period, as warm soil favors its growth. The plants attacked soon become stunted and the foliage assumes a pale, lifeless, yellow color. The disease is often more severe on one side of the plant than the other, causing it to curve towards that side. The fungus enters through the roots and passes up to the stem and leaves through the vascular bundles which it soon clogs and destroys, as well as the tissue adjoining it. As the destruction of the vascular bundles shuts off the plant's supply of food-material and water, the lower leaves soon drop off through lack of sustenance, and the whole plant either becomes sickly and fails to head or dies outright, according to the severity of the attack.

Destructiveness. — On fields moderately infected, from 50 to 75 per cent of the crop is a loss, while in badly infected fields the crop is a total failure.

How the Disease Is Spread. — The fungus is carried from field to field in a variety of ways: for example, (1) by diseased plants from infected fields; (2) by water which drains from infected fields; (3) by wind blowing the dust from field to field; (4) by vehicles, tools, and animals.

Persistence. — Once introduced into the soil, it remains for long periods, experiments extending over fourteen years having shown it to be still present and active. Soil infested with this fungus is said to be "cabbage sick," but other crops grow well in it.

Control Measures. — Various measures have been tried as a means of controlling the disease: (*a*) Disinfection of

seed and seed beds. These failed because the fungus was in the soil of the field and not on the seeds or in the seed beds. (*b*) Using new land for seed beds. This failed for the same reason. (*c*) Crop rotation, to give the fungus a chance to die out. A period of fourteen years was found to be too short, so that also was impracticable. (*d*) Fertilization of the soil with a view to obtaining such vigorous plants that they could resist the disease. No success was attained. (*e*) Soil disinfection, for the purpose of ridding the soil of the fungus. Nothing was found that was cheap enough or that would kill the fungus without being detrimental to the growth of the crop. (*f*) Finding plants able to resist the disease, based on the experience of finding now and then a head in a whole field that had been able to live when the rest were killed.

The method used was to take such heads and raise seed from them for next year's crop. These plants were found to produce a higher percentage of resistant plants, the best of which were then selected to produce the seeds for another crop. In this way strains have been developed that are practically immune to the attacks of the fungus. Much still remains to be done, but enough has been accomplished to make sure that success in combating the disease lies in producing disease-resisting plants. No one has yet discovered what the differences are that make immunity possible in one plant and not in another.

318. Potato Wart. — This is a disease dangerous to the common potato which has been known in Europe for many years, but which has been found in the United States only since 1918, when it was discovered in Pennsylvania. It was introduced on an importation of several millions of bushels in 1911, which were distributed over the eastern part of the United States. Much attention is now being given to locating centers of infection, in order that quarantines may be established.

Signs of the Disease. — The effects are found in the potato itself and not on the parts above ground, which accounts for its not being discovered till harvesting time. The first evidences of wart are small spongy outgrowths on the surface of the potato, especially at the eyes. Sometimes warts arise on different parts of the same potato, transforming it into a spongy mass which turns from brown, the first color, to black, and decays (Figure 350).

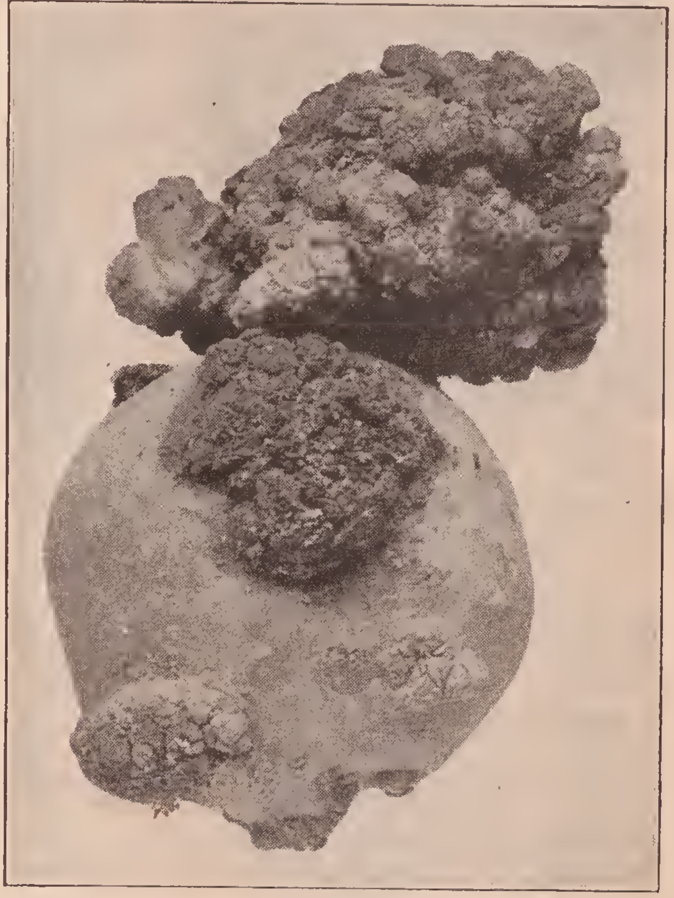

FIGURE 350. — POTATO WART.

What Causes Wart. — Wart is caused by a fungus which penetrates the outer coat of the potato and stimulates the cells to abnormal growth. When the wart decays, it fills the soil with millions of sporangia of two sorts, one capable of germinating at once and infecting new potatoes or new places on the same potato, and the other resting sporangia, capable of living over the winter and starting the infection anew in the spring, or lying dormant for years until conditions become favorable for germination.

How the Fungus May Be Spread. — (1) By drainage from infected fields; (2) by distribution of the infected soil; (3) by the use of manure of animals which have eaten the raw potatoes; (4) by garbage into which peelings from diseased potatoes have been thrown; and (5) by planting diseased potatoes or those which have grown in infested soil and carry the spores on their surfaces.

Control of the Disease. — As the result of many experiments with disinfection, fertilizers, resistant varieties, and so forth, the best means of control seems to be to destroy or boil all potatoes grown on such infested land, to establish a strict quarantine to prevent its spread, and to practice rotation of crops over the period of eight years that the fungus is known to remain in the soil. It does not cause damage to any other cultivated crop, but it may propagate itself on other members of the potato family, especially such as grow wild.

Courtesy of Experiment Station, University of Minnesota.

FIGURE 351. — NORMAL GRAINS OF WHEAT.

Note. — As an illustration of the application that may be made of biology, it may be said that the disease was first reported in this country by a biology student in high school who had noticed potatoes in the field at home, but had not known the cause of the peculiar appearance or the seriousness of the disease till his teacher mentioned it in class.

319. The Black Stem Rust of Grain and the Barberry. — The black stem rust of grain causes the loss of millions of bushels of grain every year. In 1916, a bad rust year, the loss in wheat alone in a single state, Minnesota, was about 30,000,000 bushels. In 1917, not a bad rust year, the loss in the whole United States was about 1½

Courtesy of Experiment Station, University of Minnesota.

FIGURE 352. — GRAINS OF WHEAT AFFECTED BY BLACK RUST.

per cent of the whole crop. The wheat affected by rust has shrivelled grains, which are light in weight, and straws which are crinkled and broken.

The Cause of the Rust. — This is a fungus which lives as a parasite on the stalks and heads of grains and grasses during a part of its life history, and on the leaves of the common barberry for the other part. This is spoken of as the alternation of hosts, a habit which is characteristic of several other fungi which cause plant diseases (see page 380).

Courtesy of Experiment Station, University of Minnesota.

FIGURE 353. — DISEASED HEADS OF WHEAT.

How It Spreads. — The fungus itself is composed of very small threads or hyphæ which grow inside the leaves and stems of the host plant. It spreads from one wheat plant to another by means of spores which are carried by the wind, insects, or other means. In the early part of the summer these spores appear in red pustules on the stems and leaves of the infested plants, from which they fly like dust when the plants are disturbed. On account of their small size and large numbers, they fall on other plants,

some near at hand, and some long distances away. When moisture makes it possible, each spore sprouts and forms a new center of infection. These spores, called summer spores, are red or orange colored and egg-shaped. In the autumn another kind of spore is produced, namely, the black or winter spore. These appear in black pustules on the stems and leaves of the plants which serve them as host. These spores are longer, and have thick walls, an adaptation which enables them to live over the winter in stubble and straw. They are made up of two cells, and usually are not carried by the wind.

Courtesy of Experiment Station, University of Minnesota.

FIGURE 354. — HEADS OF WHEAT UNAFFECTED BY BLACK RUST.

When they germinate in the spring, each of the two parts produces four round, colorless bodies called sporidia. These are blown about by the wind, but they are not able to propagate the disease unless they fall upon the barberry, where they produce a plant so different in appearance that it was for many years considered a separate plant and given a different name. On the leaf or fruit of the common barberry, the sporidia produce yellow circular spots containing reddish spores in long chains. From the shape of the spot, this is often called the cluster cup stage. This stage is most active from May until midsummer. The spores from the plant on the barberry

cannot reproduce on the barberry, but on being blown to the grains or certain grasses, they begin a new stage in the life history of the red rust. These propagate on the grain in the field as before. Another source of infection is the summer spores which may have lived over the winter on the grasses near the field, or on straw or stubble. A summary will put the history clearly: (1) the red or summer spores spread the disease from wheat to wheat, or from wheat to grasses and back to wheat; (2) the winter spores formed on wheat or grasses in the autumn remain on them until spring when, by means of sporidia, the infection of the common barberry takes place; (3) the cluster cups or spring spores on the barberry start the infection again on the wheat and grasses.

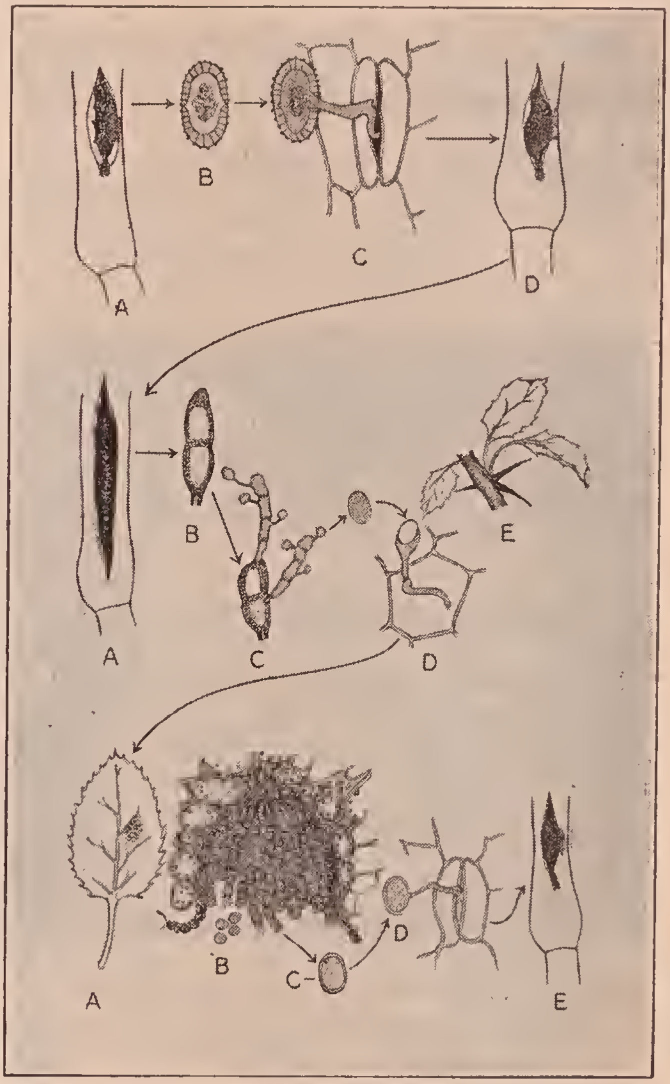

FIGURE 355. — DIAGRAM OF LIFE HISTORY OF RED RUST OF WHEAT.

Conditions Favoring the Rust. — Cool nights with heavy dews, followed by hot muggy days, afford ideal conditions for the growth of the disease. Any condition which favors the growth of the grain and retards that of the rust is unfavorable to the disease.

Methods of Control. — No sure means has been found of curing the disease, but experiments have proved that there are several ways of reducing the amount of damage done by it. Among them may be mentioned clean cultivation,

which gets rid of the grasses on which it grows; planting early varieties of grain which mature before the rust has time to develop; planting varieties which have been found able to resist the disease; and, best of all, getting rid of the common barberry. Denmark, which eradicated the barberry in 1903, has not had an epidemic of rust since.

Note. — The Japanese barberry, more commonly planted for ornament than the common barberry, is immune to the rust, and may be spared.

320. Plant Breeding. — Plant breeding is a general term for the various methods employed to improve a given variety

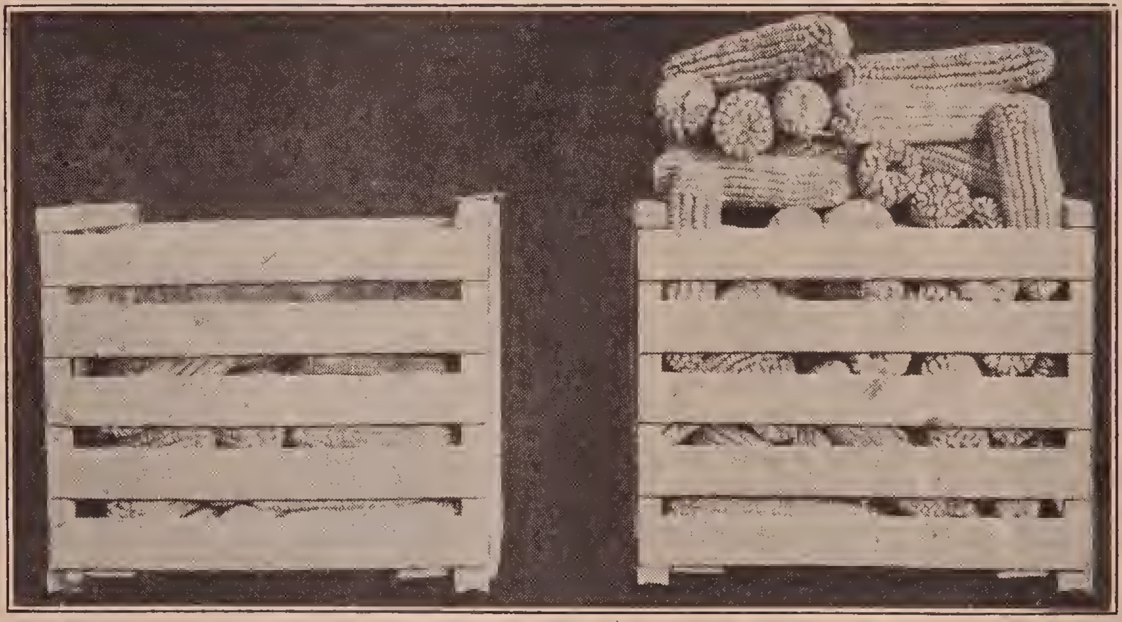

FIGURE 356. — VARIATIONS IN YIELDS OF GOOD SEED CORN FROM ROWS PLANTED WITH SEED FROM TWO DIFFERENT EARS.

Crate on left, row 18, 19 pounds seed corn; crate on right, row 11, 62 pounds seed corn. Good seed corn worth three dollars per bushel in the ear. Only the ears from the high yielding rows are retained as seed corn for further experiments.

of plants. It is well known that there is a wide range of variation (page 390) in plants as they grow in a field. In the case of food-plants, it is desirable to know the conditions which enable a plant to produce the most food. We are just beginning to understand some of the reasons why one plant is large and another small, why one plant gives a large

yield of seed and another a small yield. But it must be remembered that we are only at the beginning in our understanding of some of these problems. The methods of breeding oats serves to illustrate why it is important that we know more about plant breeding and also illustrates the general problem.

321. Methods of Breeding Oats. — The oat crop ranks third in New York State, having an annual value of about twenty

FIGURE 357. — TYPES OF HEADS OF OATS (see text).

million dollars. The average yield per acre when the study of breeding oats was undertaken was about thirty bushels per acre whereas it should be not less than forty bushels per acre.

The first step is to secure good seed which will produce large, healthy plants. Students of commercial oats recognize

a dozen different types, and the first question to be settled is which shall be selected. This point is well shown in Figure 357, which has two types of heads common in a field of oats. On the right is a branched head; on the left, the oat kernels are mostly on one side. Both these heads yield well, but the head that has the kernels on one side shows a greater tendency to lodge during a heavy wind or rainstorm, which makes this variety difficult to harvest.

Before selection can be wisely undertaken, it is necessary to know the locality or environment in which the seed is to be sown and to learn which variety is best adapted to the locality. Some varieties are more resistant to drought than others, some are more susceptible to rust or more affected by smut, while others have stiffer straw, thicker hulls, or larger grain.

Those who are making the experiments in plant breeding try to combine in one variety the best features of all, but it is difficult to produce just the results most desired. Many varieties of plants are improved regularly in nature by cross-pollination. In plant breeding man has taken advantage of this habit in plants and substituted pollen from a special variety when he sought to grow a plant with special features. But oats are regularly self-pollinated and when cross-pollination is to be effected, the oat flower must be opened before it reaches the blooming stage and the three anthers must be removed. Then the flower is carefully closed and allowed to mature for two days before the pollen from the plant of the variety to be used is dusted on the pistil.

The oat illustrates one of the difficulties which the plant breeder encounters. Each variety of plant has to be studied in just such a detailed fashion before any permanent improvement can be secured by plant breeding, which has become one of the most difficult and technical phases of plant study.

322. Conservation. — Conservation is a term which was frequently heard during the war, in connection with sugar, coal,

gasoline, and other articles of daily use. A broader use of the word includes our natural resources, such as land, water, and mineral wealth, as well as the more personal ones.

Conservation of land is being accomplished in three distinct ways, as follows:

1. *The Reclamation of Desert Land by Irrigation.* — This is carried on in the western United States where the rainfall

FIGURE 358. — IRRIGATING DITCH.

is so scanty that only a few plants, especially adapted to extremely dry conditions (see page 371) can live. This region, although now a desert, lacks only water to make it productive. The water for irrigation is secured by building dams in suitable places and storing throughout the summer the water from spring freshets and melting snow on the mountain peaks. Closely connected with this phase of land conservation is *dry farming*, so called. This is possible as strains of wheat and other crops have been found which can

grow with much less moisture than the ordinary strains demand. The use of such strains makes crops possible on land too dry for farming under ordinary conditions.

The use of water for irrigation has been practiced from very early times especially in India and Egypt. The methods used there, and the results obtained, however, are insignificant when compared with modern methods, a good example of which we find in the western United States. Immense dams are constructed which impound lakes covering many

FIGURE 359. — IRRIGATING DITCHES.

acres. The water from these lakes is let out, carried miles through canals and tunnels, and is distributed to crops as needed. In this way, nearly a million of acres have already been made fertile which before were unable to produce crops on account of the absence of rainfall.

This work in the United States is carried on by the government under the name of *reclamation projects*. More than twenty such projects have been successfully carried out, and the land sold to settlers at reasonable rates. More than twenty thousand persons are now living in regions formerly unfit for habitation. It is estimated that there

are about thirty millions of acres that can be reclaimed by carrying on this work.

Any crop can be raised on irrigated land that the character of the soil and the climate make possible. All kinds of fruits are produced in abundance in some portions of the western irrigated lands, on others garden produce is raised, and on still others grains and hay.

2. *Reclamation by Draining.* — This was formerly done only by private individuals and on a small scale. Within the last ten years, however, the United States Government has undertaken drainage projects on a large scale, especially in the Everglades of Florida. The plan is to cut through the rim of land that hems in the swamps and form a channel to the ocean for the water which now covers the land from a few inches to ten feet or more in depth. The main ditches will be large enough to serve also as canals for transportation, and for the distribution of water for irrigation in dry seasons. The work already undertaken will make available about 4,000,000 acres of land now useless.

In New York State, the building of the Barge Canal has made it possible to reclaim by drainage the large tract known as Montezuma Swamp at the foot of the finger lakes. Hundreds of acres now covered only with cat tails and other worthless plants will be suitable for truck farming, being fertile, level, and unusually free from stones.

Swampy land near the ocean is often reclaimed by building a loose retaining wall around it, and pumping in sand, mud, and gravel from the beach or from some other part of the swamp or marsh. Such land has little value for agricultural purposes, but it affords safe and convenient sites for buildings.

As the population increases, and the demand for food grows stronger, more pains will be taken to make the best use of all land. Other countries are much in advance of ours in this respect.

3. *Rejuvenation of Worn-out Land.* — In the eastern part of the United States there are many farms which have been abandoned because the soil has become so poor that there is no profit in the crops raised. This condition has come about gradually by taking crops off, year after year, without replacing food material for succeeding crops. Fertility can be restored by supplying proper fertilizers and by the rotation of crops some of which must be leguminous. (See page 257.)

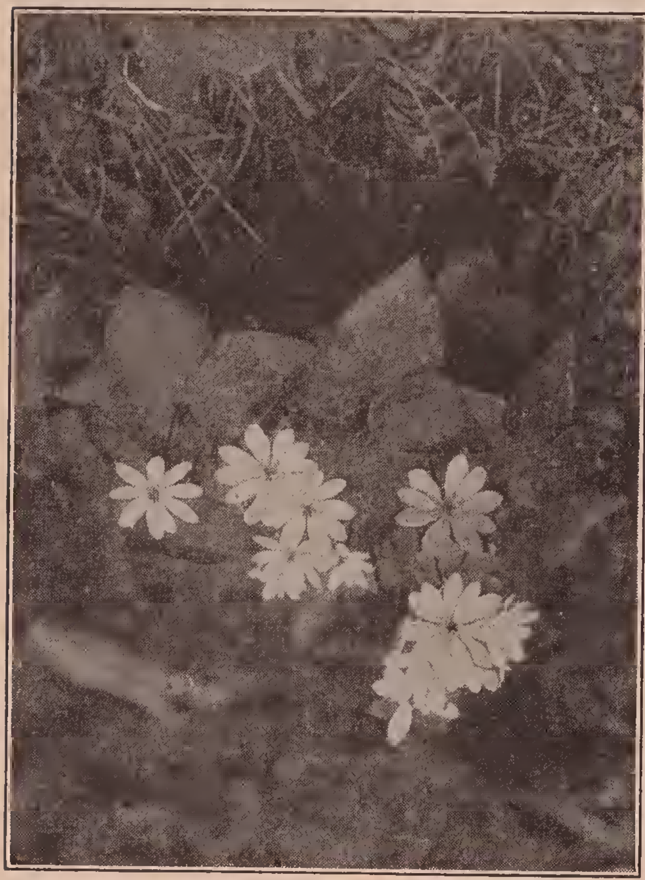

FIGURE 360. — HEPATICA.

One of the earliest wild flowers, and one of the greatest favorites. It should be left growing in its natural surroundings, and not transplanted as a common practice is. Only a part of the blossoms should be picked from each bunch, in order that some may be left to mature and scatter seed.

323. Conservation of Wild Flowers. — The main reason for the study of fungal diseases, plant breeding, and the general problem of conservation outlined in this chapter is their economic importance to man. From time to time in the discussion of animals and plants in the previous pages of this book, your attention has been called to facts about living things without any thought of their direct economic bearing. In each instance we have been trying to give you a clearer understanding of how animals and plants live, in the hope that some of this information will give you pleasure in the future.

It would be a poor course in biology that did not emphasize the pleasure which knowing our wild flowers gives all lovers

of nature. We are coming to feel that animals and plants which give pleasure to us should be permitted to live. Game laws and animal preserves are helping to protect some of our rare animals that were being destroyed by man. The time has come when similar provisions should be made for our choice and rare plants.

FIGURE 361. — FRINGED GENTIAN.

One of the flowers that is eagerly sought after by flower pickers, as a result of which it is becoming less and less common. As it is an annual, picking all the flowers prevents its further growth in that region. This flower should not be picked by friends of wild flowers.

Owing to the limited area of wild tracts, particularly near cities, wild flowers will soon disappear utterly unless the public is educated to enjoy them as they grow. The study of plants which you have just made tells you about their habits so that you may know how to deal with them. For instance, little harm is done by picking the flowers of trillium, because its thickened stem, deep in the ground, will put up another flower stalk the next year, if it has food enough stored to enable it to do so. In the case of arbutus, however, it is difficult to pick the blossoms without pulling loose from the soil the long trailing stem, which is then left to die. In your study of the flower, you have learned that the seeds are developed in the flower and if you pick all the flowers, no seeds can be formed. Lovers of wild flowers

FIGURE 362. — PINK LADY-SLIPPERS.

One of the disappearing orchids. In many places incessant picking has exterminated it. It is doomed to extermination unless the boys and girls start a crusade to save it from the older men and women who are old-fashioned in their way of appreciating wild flowers. Orchids are perennials but they need their leaves to store up food for next year's blossoms and seeds. Naturally they fruit every year, and the older plants are surrounded by little groups of seedlings, which is nature's way of stocking the woods with these delightful flowers. Every one that is picked and brought in tends to make the woodland barren and so much less attractive. Spare the wild flowers!

are coming more and more to enjoy leaving them where they grow instead of picking them for decorating their homes, where they last for only a few hours at best.

Photographing wild flowers where they are found growing is a form of recreation that is becoming popular.

SUMMARY

No one can be a successful agriculturist or a successful forester without having a knowledge of what plants are, how they grow, what conditions suit each kind of plant best, how to till the soil to secure those conditions as nearly as possible, what the relations are among the plants themselves and what the relations of other organisms are to plants, especially to cultivated plants. This makes necessary a wide study of insects, the worst enemies of plants, and of birds, the enemies of insects, also a study of bacteria and of fungi, which cause large losses to the farmer in attacking the crops he is raising. Until we realize how complex these relations are and how much depends on knowing them, we shall, as a nation, never make the best use of the resources we have. The study of biology ought to help boys and girls to think about these things, and to make applications of them in their everyday life.

QUESTIONS

What is the use of studying plants scientifically? Name the plant diseases discussed. Tell how each is caused. What is the remedy for each? What is plant breeding? What are the objects of plant breeding? What is conservation? In what ways is land being conserved? Why should wild flowers be conserved? How can this be accomplished?

HOME WORK

Make a list of the plant diseases you know. Try to find out what causes each and how it injures the plant. Make a list of the remedies you know of for each disease, such as sprays. Find out from the owner of a farm how many bushels of each crop his land produced to the acre. Compare this with the average for the United States. Account for the difference. What can be done to improve a low yield? Make a list of the wild flowers that grow in your locality. Inquire from some older person what flowers formerly grew there in abundance. What can you do to help save those that remain? If you own a camera, try making photographs of wild flowers growing in their natural surroundings.

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PART III

HUMAN BIOLOGY

CHAPTER XXX

RESEMBLANCES BETWEEN MAN AND THE OTHER ANIMALS

324. Man as an Animal. — In our study of animals and plants, the life processes have been emphasized. We have found that each living thing can be analyzed according to the place where it lives and its food habits; its structures used in securing life-giving oxygen and removing wastes; its organs for responding to light, heat, cold, sound, etc.; and finally its methods of producing more living things like itself. We also found in plants an additional life process, the ability to manufacture their own food from the uncombined and non-nutritious elements in the air and soil. As we approach the study of man, we naturally ask how all these facts that we have learned about animals and plants help us to understand how man lives.

One of the best ways to learn about man is to study his life processes just as we did the grasshopper's and the frog's. In such a study we may omit the comparison with plants except incidentally, because man is an animal in all the points in which our comparison is to be made, and the similarities between animals and plants have already been emphasized on pages 4–8. This does not imply that man is nothing more than an animal, but simply that in many features of his life he lives as animals live.

Some of the men who have made a special study of the fossil remains of man in the rocks believe that man began living in Europe about 25,000 years ago. This is their estimate of the length of time that has passed since the rocks were formed in which are found jaw bones or the bones of the legs and arms. In all such cases so far there has been no difficulty in recognizing these fossil bones as belonging to man, although the races of people who lived fifteen or twenty thousand years ago no longer exist.

The earliest homes of man must have been the shelter of trees and an occasional cave, and it is in certain caves in Spain and France that many early records of man are to be found. There is no record of when man first began to use fire or to build definite shelters. In fact, both these necessities in our cold climate were not as important to early man, because he appears to have wandered about in tropical and sub-tropical regions. This was even true of the climate of Spain and France in the period when he lived in the caves which have become famous for their many records of the early life of man. With the coming of the glacial period, the climate of all northern Europe and northern America became much colder and the men who lived in regions that were influenced by the southward movement of the ice sheets had to adopt some means of keeping warm or perish.

But as soon as the number of men became so great that they needed to go farther for the necessary food, we may suppose that protective measures were gradually used. Moreover, the same forces that compelled early man to migrate have continued to impel man to move out into unknown parts to see if he can find an easier place to live. We shall see how this has come to have a vital influence upon our own lives as we examine more fully into man's life processes.

We have lived in houses heated in winter so long that we had begun to feel that it would be impossible to get along

without a furnace fire; but we have all read how whole sections of France during the war had no heat and that our American soldiers were able to adjust themselves to what seemed to most of us an almost impossible change. This teaches us two important lessons: first, it shows something of how early man may have lived; and secondly, the wide range of adaptation in the body of modern, civilized man. This second lesson is very important because it encourages us to undertake physical difficulties which we had thought impossible; because we now realize that we can overcome them after having the heroic examples of the men, women, and children of Belgium and France.

It is also easier now than ever before to realize how man can live in all parts of the earth. When we described where frogs, fish, and grasshoppers were to be found, certain limits had to be made. Not so with man. He possesses something that no animal has — the power to rise above the limitations of his surroundings. This he does by building a house of ice in the northlands and spreading a tent of cloth in Arabia. His constructive ability has led man to invent various devices for his protection such as stone, brick, wood, or iron houses, something that no animals are able to do in a manner that justifies their being compared with man in this respect. It is true that birds build nests, but they are always built in the same fashion; and it is true that beavers build dams, but they are always made of wood. The reason that man is able to do more different things than animals is because he has a better mind, a mind that can adapt itself to many different kinds of work, such as that done by carpenters, engineers, lawyers, teachers, etc.

Name some others. Tell what you can about the range of adaptation in animals that have not been domesticated by man. These simple and well-known comparisons give us some indication of the sense in which man and animals are similar and it is in this sense that we wish to work out the

comparison of the life processes of man with those of animals.

Scientists give four reasons in explaining why certain animals and plants are not adapted to living in all parts of the world: (1) lack of suitable food; (2) failure in adapting their lives to the peculiarities of climate; (3) too many enemies; (4) inability to raise their young. All these man has been able to overcome.

STUDENT REPORT

The following table points out some of the common adaptations in animals. How are they related to the animal's success in life? Name some other habits which help to protect animals.

	Active in Summer	Active in Winter	Home				Protection				
			Earth	Water	Air	Nest	Night Feeding	Day Feeding	Color	External Skeleton	Method of Escape
Earthworm											
Fly											
House Sparrow											
Dog											
Man											
Etc.											

325. Youth, Maturity, Old Age. — The life of man is divided into three general periods, which are youth, the period of maturity, and the period of old age. These same terms are given when describing the life of animals and plants.

Youth is the period when living protoplasm always grows, if furnished with proper food. This is the time when boys and girls grow taller and heavier each year; when the tree grows new leaves and the limbs become longer; and when

the small puppy is turning into a full grown dog. During this period of change the boys and girls, the tree, and the puppy are all nourished by food and this makes it possible for them to grow.

Maturity is the period when man ceases to grow taller, although he continues to eat food as he did during the period of youth. The living protoplasm in his body does not increase in amount. The same can be said of the tree, for it does not grow taller; and the puppy of last year has become a full grown dog. During this period of maturity, each living organism is able to repair its body as fast as the body wears out. The period of maturity varies with different things; in some butterflies lasting but twenty-four hours, in man continuing for about twenty-five years.

Old age in man begins when the body wastes faster than it is repaired, and in the tree when growth is over and decay begins. During this period of old age all living things use food as they did in youth and maturity, but it cannot build up the body as fast as it is worn out and death is the final result. Old age occurs at different ages in different individuals; and the same is true of animals and plants.

SUMMARY

Man has the same life processes as the animals. He is able to live in all climates and localities on the earth. No plant or animal can do this. Civilized man has learned to control his surroundings. Animals and plants *are controlled* by their surroundings. Man like all other living things passes through periods of growth, known as youth, maturity, and old age.

QUESTIONS

What have you learned about plants and animals that will help you to understand how man lives? Where are the earliest records of man found? Why do men migrate? Why can man control his environment? How do you understand the terms youth, maturity, and old age?

CHAPTER XXXI

DIGESTIVE ORGANS AND FOOD

326. Digestive Organs. — The digestive organs of man consist of the same parts which have already been described in the frog. Each region of the digestive organs is more perfectly developed and the biological principle, the division of labor, reaches its highest development in man. The parts of the alimentary canal in man are: the mouth, containing the teeth, tongue, and glands; the throat or pharynx; the esophagus, the stomach, the small and the large intestine. The last part of the large intestine is called the rectum. These several parts form a continuous tube, and each does a particular work in digestion (Figures 363 and 72).

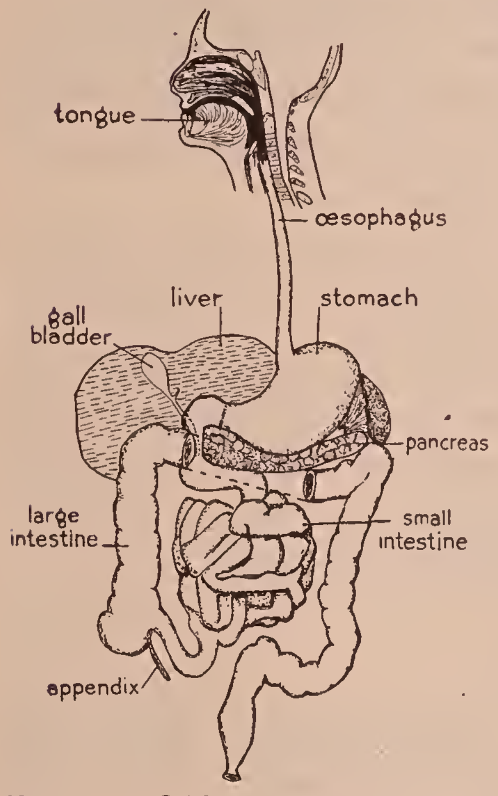

FIGURE 363. — ALIMENTARY CANAL OF MAN, WITH ITS TWO CHIEF DIGESTIVE GLANDS, THE LIVER AND PANCREAS CONNECTED WITH THE SMALL INTESTINE.

The spleen is not a digestive gland. The salivary glands connect with the mouth and are not shown.

The mouth is lined with a soft membrane, kept moist by the saliva secreted by three pairs of glands, and poured into the mouth in sufficient quantities to moisten the dry food and thus assist in swallowing. The tongue is a muscular organ and bears on its upper surface many small fleshy projections called *papillæ* (pȧ-pĭl′lē: Latin *papilla*, bud), some of which are fairly large

and are arranged on the back of the tongue in the form of a V (Figure 364).

Our power to taste sweet, sour, bitter, and salt, which are the four fundamental tastes in man, is due mainly to certain nerve cells located on the larger papillæ. The food stimuli received by the special sensory cells of the papillæ are carried to the brain by the taste nerves. In the brain the food stimulus is interpreted as sweet, sour, or bitter (Figure 365).

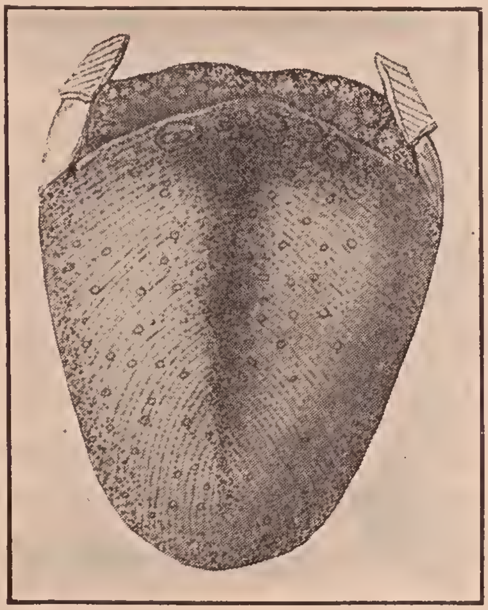

FIGURE 364. — TONGUE OF MAN SHOWING TWO OF THE THREE KINDS OF PAPILLÆ.

The circumvallate papillæ are at base of tongue and about five or six in number; the fungiform papillæ are numerous, round, mushroom-like projections scattered over the surface of the tongue. The third type of papillæ, the filiform, are the most numerous and like coarse hairs. You can recognize these papillæ on your own tongue.

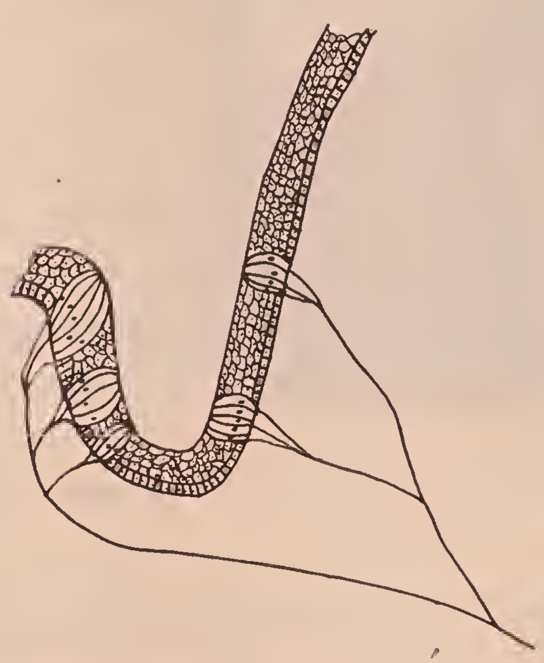

FIGURE 365. — DIAGRAM OF TASTE CELLS IN THE TONGUE.

The taste cells are much longer than the surrounding cells. The nerve which carries taste stimuli to the brain ends among these long cells.

LABORATORY STUDY

Blindfold in turn several members of the class and have each hold his nose while a small amount of some highly flavored food is placed on the tongue. Such common foods as maple sirup, vanilla extract, marmalade, jams, etc., are admirable for this test. Make a record of each

test. This experiment will prove that we do not taste flavors. Remove the hand from the nose and again taste the same substances. This time there will be no difficulty in telling the name of the substance because it has been smelled as well as tasted.

The roof of the mouth is called the *palate.* The front part contains supporting plates of bone and is therefore called the hard palate. The back part (the soft palate) is a thin sheet of muscle covered by the mucous (mū′kŭs) lining of the mouth. The soft palate separates the mouth from the nasal cavity. Beyond the soft palate is the throat cavity called the *pharynx.* This is a funnel-shaped cavity, having two openings at its lower end, the front one being the opening into the windpipe which leads to the lungs, and the rear one, the opening into the esophagus. In the upper part of the pharynx, on each side, is the opening of a *Eustachian* (ū-stā′kĭ-an) tube which passes to the middle ear.

FIGURE 366. — X-RAY OF THREE TEETH.

Note how firmly the bone fits around the roots. These teeth are in good condition. The white blotches on the molar tooth are the places where this tooth has been filled. This is the new way of examining the teeth.

Teeth. — Just back of the lips are the teeth. In adults there are thirty-two, sixteen in each jaw, belonging to four classes according to shape. In front are the eight *incisors* (in-sī′zers) with sharp cutting edges; next the four sharp-pointed *canines* (kā′nīns), and back of the canines the eight *pre-molars* (prē-mō′lers) shaped for tearing and crushing, while the remainder of the teeth, twelve in number, are the flat-topped *molars* which do most of the grinding of the food.

Care of the Teeth. — We all know that the teeth are hard. That, however, does not prevent them from becoming broken by carelessness or accident, or from decaying because of

neglect. When the teeth are not cleaned, a substance called tartar forms on them, which prevents the bacteria from being rubbed off and sometimes pushes the gums away from the teeth. The bacteria cause food particles to ferment and form acids which dissolve the hard outside covering (enamel) and then rapidly the softer parts of the teeth. This results in toothache, a foul breath, and the imperfect chewing of the food. The teeth should be brushed after each meal to remove particles of food, particularly sugar which ferments easily. At least once a year there should be a visit to the dentist who will remove those portions of teeth that are decayed and fill cavities, thus preventing further decay.

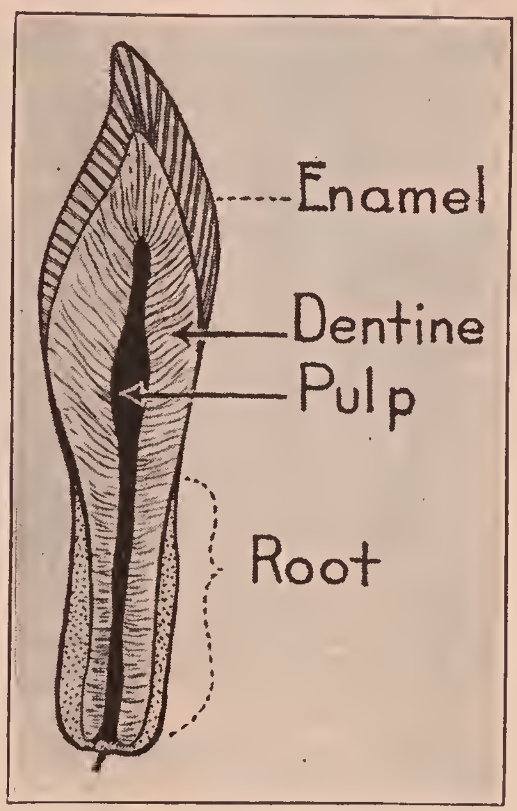

FIGURE 367. — VERTICAL SECTION OF TOOTH.

The teeth of children often come in on the outer or inner side of the jaw instead of on the middle. This results in an irregular row of teeth. Such teeth do not meet the opposite teeth as they should (Figure 369). Dentists know how to straighten such teeth and produce better results, if they can begin their corrective treatment before the teeth are fully grown. This is very important not only for one's looks but especially for one's health as without such treatment proper mastication is often impossible.

FIGURE 368. — MILK TEETH.
Age $3\frac{1}{2}$ to 4 years. Notice the permanent teeth deeper in the jaws.

The *esophagus* is a nearly straight tube connecting the mouth with the stomach. It passes through the *diaphragm* (Figure 395), enlarges, and becomes the stomach. As soon as one swallows, control of the food is lost, and further action becomes involuntary. Two sets of muscles, one extending lengthwise, the other around the esophagus, act together in forcing the food or water into the stomach. This explains why we can drink from a brook when the head is much lower than the stomach.

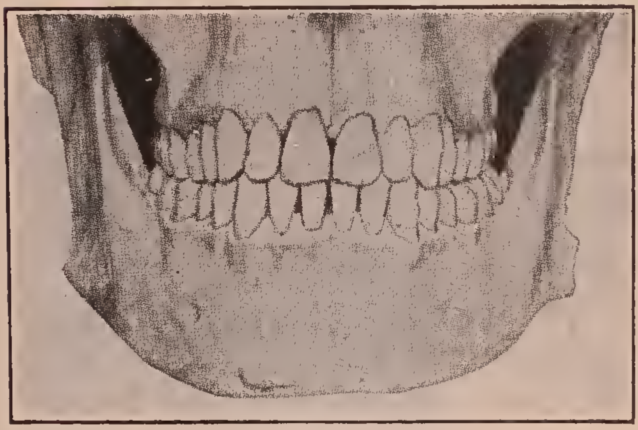

FIGURE 369. — PERMANENT TEETH.

Stomach. — In man the stomach is the largest section of the digestive tube, and it has a capacity of about three pints. It is usually described as pear-shaped although there is much variation in its form (Figures 370 and 371). At the point where the esophagus joins the stomach there is a muscular ring (*cardiac* valve, kär′dĭ-ăk) which ordinarily prevents the food from passing again into the esophagus. In vomiting, this valve becomes relaxed. The opening at the larger and lower end of the stomach is guarded by a similar valve (*pyloric*, pĭ-lŏr′ĭk) which serves to retain the food in the stomach until certain digestive changes have taken place.

FIGURE 370. — PEAR-SHAPED HUMAN STOMACH.

The intestine has two parts, a small, much coiled tube about an inch in diameter and about twenty feet long called the *small intestine*, and a large section about five feet long and four inches in diameter, bent in a rough ∩ shape and called the *large intestine*. At the junction between these two regions projects a short sac, the *vermiform appendix* (vẽr′-mĭ-fôrm ap-pĕn′dĭks). The disease called *appendicitis*

(ăp-pĕnd-ĭ-sī′tĭs) affects this organ. The large intestine ends in a special region called the *rectum*. The opening of the rectum to the outside is the *anus* (ā′nŭs).

The esophagus, stomach, and intestine are each lined with a membrane that is similar to that found in the mouth cavity. This membrane is called the mucous membrane. In the esophagus, the mucous membrane is smooth and moist thus furnishing an easy passage for the food; in the stomach this membrane is in folds except when the stomach is full of food; and in the intestine, it has a velvet appearance due to projections called villi (Figure 374). The numerous glands of the stomach and intestine are located in the mucous membrane.

FIGURE 371. — X-RAY PHOTOGRAPH OF HUMAN STOMACH.
This is a shape familiar to physicians and is just as normal as the shape shown in Figure 370.

Glands. — A gland is a group of special cells which secrete a fluid. The glands which produce the digestive fluids are (1) the three pairs of *salivary* (săl′ĭ-vā-ry) glands, located below the ear, and beneath the tongue and lower jaw; (2) the numerous *gastric* (găs′trĭk) glands found in the lining of the stomach, possibly 5,000,000 in number (Figure 373); (3) the *pancreas;* (4) the *liver*, the largest gland in the body; and (5) numerous *intestinal glands* in the small intestine.

FIGURE 372. — X-RAY PHOTOGRAPH OF LARGE INTESTINE OF MAN SHOWING APPENDIX.
The constrictions are natural.

STUDENT REPORT

Fill out the following table and describe the digestive system of the animals

studied in Part I. This will help you to understand better the parts of the digestive system of man and the work that each part does.

	One Cell	Many Cells	No Digestive Tube	Digestive Tube	No Well-defined Digestive Glands	Which Ones Require Food?
Paramecium						
Hydra . .						
Earthworm						
Frog . . .						
Man . . .						
Etc. . . .						

327. Food. — One of the best definitions of food is the following. Food is that which when taken into the body builds up tissue or yields energy. All organic foods or food-stuffs are divided into three classes, the *proteins* (prō′tē-ĭns), the *carbohydrates* (kär-bō-hī′drāts), and the *fats*. This classification is made whether we study the foods of a plant, an animal, or of man. Scientists are able to tell to which class meat, bread, oatmeal, milk, and all other foods belong by finding out the chemical composition of each. The chemists have made a thorough study of food and tell us that certain chemicals are present in each of the three classes of foods.

Definite chemical tests tell us to which of these three classes any given article of food belongs. In general it may be said that the proteins are necessary for the growth and the repair of the body, and that the carbohydrates and fats furnish heat to keep the body warm, and energy for muscular work. The unused fat is stored up as fatty tissue. All classes of food are found in the various foods obtained from plants. Some, like honey, are nearly pure carbohydrate, while the English walnut contains, in addition to fat, a large quantity of plant protein. Animal foods can furnish us with only proteins and fats. In primitive times man used a restricted diet and led an active out-of-door life. To-day

man is living on a mixed and varied diet. This is to be regarded as an acquired habit and one that is questionable when carried to an extreme. The question of how much to eat is a modern problem, and on its solution depend our health, length of life, and energy for work.

STUDENT REPORT

Animals eat a large variety of things, parts of which serve to furnish energy or to nourish the body. In the following report, work out the sources from which the animals derive their food. To what extent are they alike?

	Paramecium	Hydra	Earthworm	Frog	Man	Flies
Minute plants . .						
Minute animals . .						
Plants						
Flies						
Add food of man .						

328. Digestion. — Digestion begins in the mouth. The teeth break up the food and mix it with the fluid of the mouth, the *saliva* which contains the enzyme, *ptyalin*. During this process, sugars and starches are changed into soluble sugars. The fluids of the mouth are usually slightly *alkaline* (ăl′kȧ-lĭn or līn, a chemical term, the opposite to sour or acid), but as soon as the food passes into the stomach it enters an acid (sour) medium, and the digestive action of the saliva is destroyed in a short time by the stomach fluid. For this reason, the sugar and starch undergo no further digestive changes until they reach the intestines.

Into this acid medium of the stomach, the gastric glands (Figure 373) pour out the gastric juice (a digestive fluid), and the enzyme pepsin in this juice acts on the proteins so that they can later pass through the walls of the intestines. In the stomach the heat of the body dissolves some of the

fats into oils, but many of the fats used as food remain solid at body temperature and are unchanged in the stomach.

After one or two hours the food passes into the intestine and undergoes further changes in another alkaline medium. Here the pancreatic juice, which is made in the pancreas, comes into contact with the digested and partly digested food, causing three different changes. One is to complete the change of proteins into simpler products; a second is to finish converting starches into sugar; while the third is to assist the bile (the digestive juice made in the liver) to digest the fats. The digestion of the food is practically completed in these three regions of the digestive tube, although digestion continues to some extent after the food is passed into the large intestine.

FIGURE 373. — HUMAN GASTRIC GLAND.

The lining cells of the inner wall of the stomach project into the tissues of the stomach as minute pockets. The cells shaded in this drawing are the ones that are at the end of the pocket and are the ones that secrete the gastric juice.

The pepsin in the gastric juice is called an *enzyme* (ĕn′zīm: Greek *enzymos*, fermented) or ferment. There are three different enzymes in the pancreatic juice (trypsin, amylopsin, and steapsin), none in the bile, and one in the saliva. These enzymes are the chemical bodies which digest food. All plants and animals digest their food by means of enzymes.

Inorganic foods, such as water, oxygen, and salts, man takes into his body, making them part of his living protoplasm, or using them in oxidation. There is a large amount of water in man, enough to make up nearly two thirds the total weight of his body. All of his food contains water.

Oxygen is breathed in from the air, and the various salts, such as common salt, *sodium chloride* (sō′dĭ-ŭm klō′rĭd, or rīd), *calcium* (kăl′sĭ-ŭm), *magnesium* (măg-nē′zhĭ-ŭm, or

-shĭ-), *potassium* (pō-tăs′sĭ-ŭm), and *phosphorus* (fŏs′fŏr-ŭs) are taken in with our food. They are useful to the body. A small amount of iron is also contained in food and water and becomes a part of the red blood cells.

STUDENT REPORT

Where the Food Is Digested

	In the Cell	In the Leaf	Primitive Digestive Tube	Stomach	Mouth	Digested by Enzymes
Paramecium .						
Hydra . . .						
Frog						
Man, etc. . .						
Bean						
Yeast						

LABORATORY STUDY

Study food and food tests. Artificial gastric juice is easily prepared by taking ½ gram of pepsin, $\frac{1}{10}$ cc. of strong *hydrochloric* (hī-drō̤-klō′-rĭk) acid and adding 50 cc. of water. Take white of egg that has been cooked and subject it, in a test tube, to the above mixture. A variety of tests should be made, with and without heat (100° F.), with and without the acid. Pancreatic juice is made by uniting 15 grams *sodium* (sō′-dĭ-ŭm) *carbonate* (kär′bŏn-āt), 5 grams *pancreatin* (păn′krē̤-ȧ-tĭn), and 100 cc. water. The action of this fluid may be tested as above on the fats, as olive oil; on starch, as flour; and on proteins, as raw lean meat or milk. Also examine several of the common articles of food to determine to what class of foodstuffs they belong.

329. Absorption of Food.—The absorption of food in man and animals is the process of taking the digested foods from the alimentary canal into the blood. Practically no food is absorbed in the mouth or esophagus, and but little in the stomach.

The absorption of food from the intestinal canal is done by small folds in the lining of the small intestine. To the

naked eye, these folds appear as a covering of minute hairs, called *villi* (vĭl′lī). Their structure is shown in Figure 374.

The process of osmosis, which has been so frequently referred to in Part I, is the chief factor in the passing of the food into the blood vessels. This process is assisted by the action of the living cells in a manner not well understood.

The digested proteins and sugars pass directly into blood vessels which lead to the liver. In the liver, these blood vessels unite to form the *portal* (pōr′tal) *vein*, which is divided into minute branches that distribute the blood to the cells of the liver. As the blood thus passes among the liver cells, the larger part of the sugar is changed into *glycogen* (glī′kō-jĕn), an animal starch, and stored temporarily in the liver cells. This stored-up starch, glycogen, does not yield energy to the body. It is given out gradually from the liver and changed back into sugar in which form it does yield energy to the body and results in keeping a uniform amount of sugar in the blood.

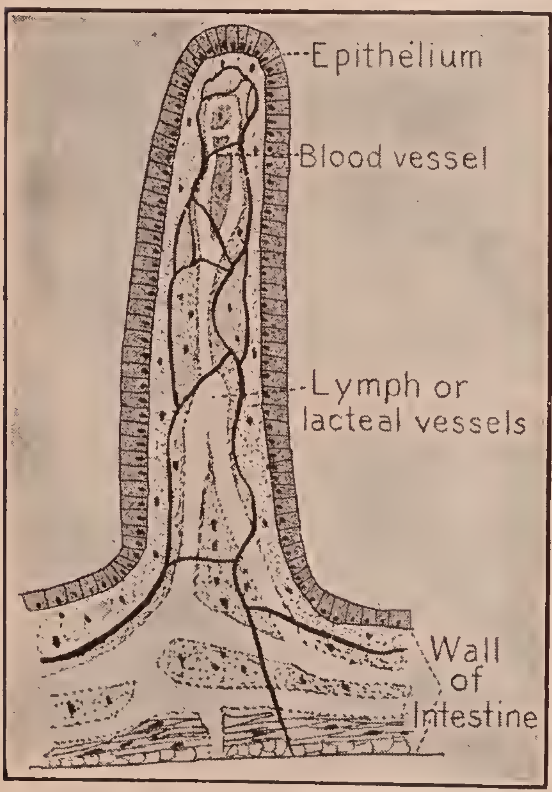

Figure 374. — Diagram of a Villus from the Inner Wall of the Intestine.

The fats pass into certain distinct vessels, *lacteals* (lăk′tē-als), which in turn open into larger ones. Eventually these vessels unite to form a large duct — the *thoracic* — which empties into one of the veins near the heart. The food is now in the blood stream and is carried to the individual cells of the body. Each cell takes the kind of food which it needs and by a series of changes, as yet only partly known, makes the food into living protoplasm.

The indigestible part of the food is not absorbed, but continues to move through the small intestine into the large intestine, and on through the rectum. During this progress much moisture is absorbed, especially in the large intestine, which leaves the "undissolved food" harder and harder. The regular removal of the unused part of the food, *fæces* (fē′sēz), is of much importance in maintaining health, because the bacteria living in the digestive tract cause the waste material to decay and the poisonous substances thus formed are injurious when absorbed into the blood.

Foods normally remain in the stomach from one to five hours, and in the small intestine about four hours; while they may be from six to twenty-four hours in passing through the large intestine.

We become hungry each day and feel relieved only after eating. A person frequently eats a large meal because of an extra amount of work that is to follow. But is he helped to do the extra work? Probably not, for the strength to do the work of to-day comes from the food eaten yesterday, or possibly the day before yesterday. The food, even after digestion is completed, must pass through many changes before it is built up into protoplasm. The actual building of the food into protoplasm is the process for which the word *nourishment* is used, and it should not be confused with *absorption*.

- Food as purchased contains
  - Edible portion
    e.g., flesh of meat, yolk and white of eggs, wheat, flour, etc.
    - Water.
    - Nutrients
      - Protein.
      - Fats.
      - Carbohydrates.
      - Mineral matter.
      - Vitamines (vī′tȧ-mĭnz).
  - Refuse
    e.g., bones, entrails, shells, brain, etc.

Alcohol is made up of carbon, hydrogen, and oxygen. All proteins contain nitrogen in addition to these three.

Because alcohol contains no nitrogen, it cannot be used as a food to build up tissue.

USES OF NUTRIENTS IN THE BODY

Protein *e.g.*, white (albumen) of eggs, curd, casein (kā′sē̇-ĭn) of milk, lean meat, gluten of wheat, etc.	Forms tissue	All serve as fuel to yield energy in the form of heat and muscular power.
Fats *e.g.*, fat of meat, butter, olive oil, oils of corn and wheat, etc.	Are stored as fat	
Carbohydrates *e.g.*, sugar, starch, etc.	Are transformed into fat	
Mineral matter (ash) *e.g.*, phosphates of lime, potash, soda, etc.	Shares in forming bone, assists in digestion, etc.	
Vitamines found in milk, eggs, meat, fruit, vegetables, and whole grains	Help keep people well and promote the growth of children.	

Heat is a form of energy and one of the reasons for taking food is to keep up the supply of this energy. The more work a person does the more energy he uses, but even a resting body uses some energy, for the heart beats and the muscles of the chest move. The amount of this form of energy a person uses is measured by a unit of heat named the *calorie* (kăl′ō̇-rĭ). A calorie represents the amount of heat required to raise the temperature of a pint of water about four degrees Fahrenheit. A man in rising from a chair, walking eight feet, and returning to the chair uses about one calorie of energy.

The term calorie just defined is now used throughout the civilized world as the common unit of measurement for food energy. Through the studies of experts it has been determined how many calories are necessary to keep the human body from starvation, how many more must be added if the body is to do light physical work, and how many more if heavy manual labor is done. By knowing the total number

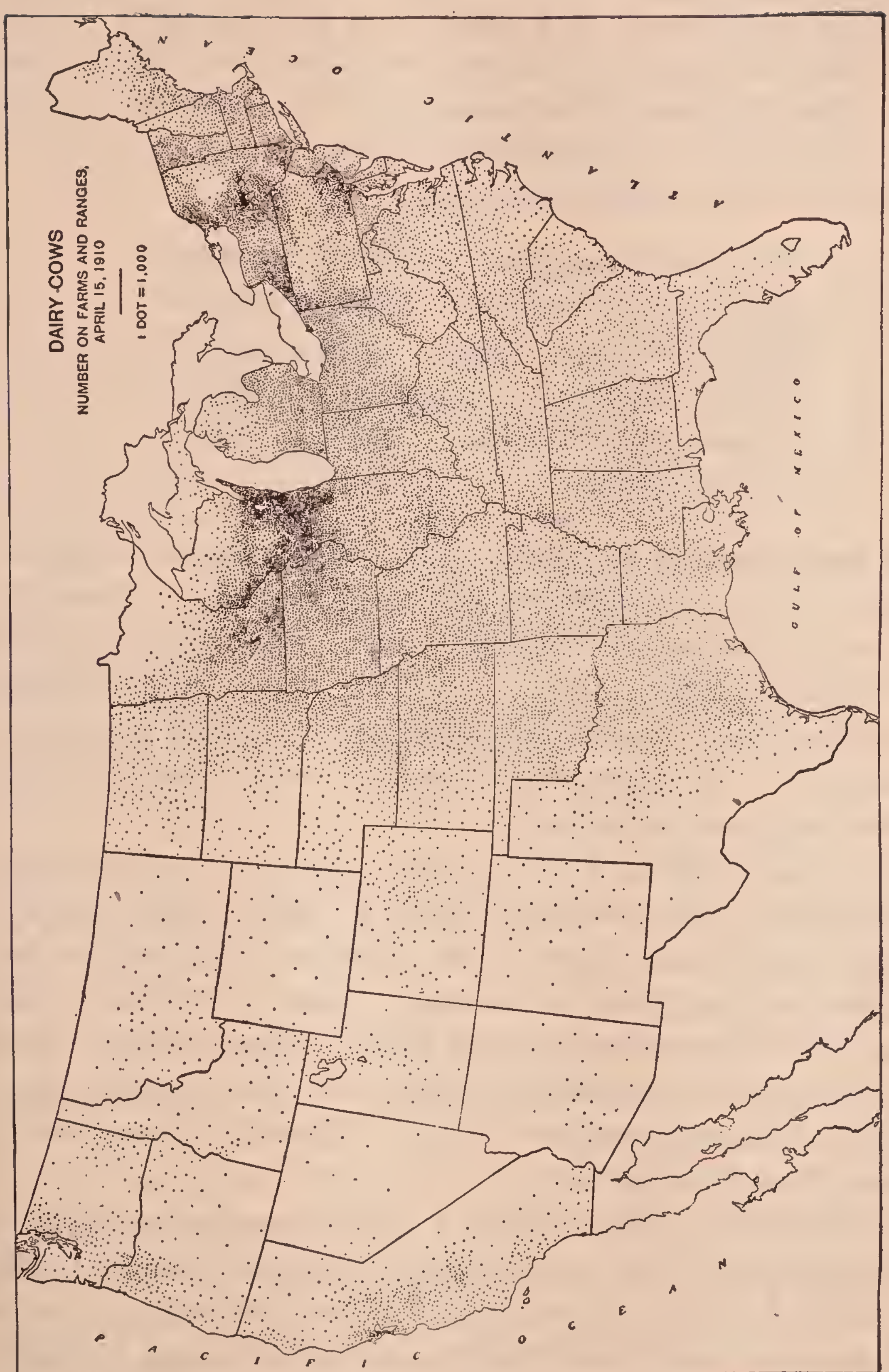

FIGURE 375. Which states furnish the most milk, butter, and cheese? Which the least?

of people in a city and the average amount of work done, it is possible to estimate how much food must be sent to this city to keep the people alive and to enable them to do their work. The adoption of the calorie unit thus serves to introduce accuracy into all calculation of food uses.

What the daily calorie needs are:

For a workingman	3500 to 4000
For an active woman	2800 to 3000
For a sedentary man	2200 to 2800
For a sedentary woman	1800 to 2300
Youth 14 to 16 years	1500 to 3200
Active soldier	4000

One must keep in mind that our bodies require energy to grow new cells and to keep the old ones in repair; to keep the body at a constant temperature winter and summer; and to furnish energy for muscular activity, which often requires more energy than to carry on growth and maintain a constant temperature. To meet these needs of every human being a variety of foods is needed.

In the classification of foods given on page 13 into proteins, carbohydrates, fats, mineral matter, and vitamines, the arrangement is made upon their chemical composition because foods do not grow as proteins or fats. The foods that we eat are often composed of all these. There are five food groups which are arranged chiefly on the proportionate amounts of proteins, sugars, or fats. These are shown in the table on the following page.

A well-balanced diet contains a proper proportion of these five food groups. One food from each of these groups should be used each day. It is impossible to prescribe an exact diet for every one, as it should vary with the age, weight, health, occupation, and location of the individual. The variation, however, is largely in the quantity rather than in the kind used.

Food Groups	Purposes	Amount Needed Daily by a Man at Moderate Muscular Work
No. 1. — Fruits and vegetables.	To give bulk and to insure mineral and body-regulating materials.	$1\frac{1}{2}$ to 3 pounds.
No. 2. — Medium-fat meats, eggs, cheese, dried legumes and similar foods, milk.	To insure enough protein.	8 to 16 ounces (4 ounces of milk counting as 1 ounce).
No. 3. — Wheat, corn, oats, rye, rice, and other cereals, potatoes, sweet potatoes.	To supply starch, a cheap fuel, and to supplement the protein from Group 2.	8 to 16 ounces (increasing as foods from Group 2 decrease).
No. 4. — Sugar, honey, sirup, and other foods consisting chiefly of sugar.	To supply sugar, a quickly absorbed fuel, useful also for flavor.	$1\frac{1}{2}$ to 3 ounces.
No. 5. — Butter, oil, and other foods consisting chiefly of fat.	To insure fat, a fuel, which also adds to the richness of food.	$1\frac{1}{2}$ to 3 ounces.

330. Source of Food. — The food necessary to the life of man must all be grown — must have all been alive at one time. In this respect man is exactly like all plants and animals. Before the miller can prepare the flour, the wheat grain must be planted, grow into a mature plant, and produce more wheat grain. There is no short cut in the growing of wheat, nor has any man a patent on the process. Man can neither lengthen nor shorten the general growth period necessary. The same is true of all food groups. Meat and eggs pass through a growth period that is just as definite and regular for them as are the periods of growth for wheat or corn. In the final analysis man has to wait until nature has produced the various food groups before he can utilize them.

Intimately associated with the ultimate production of our

foods are many biological problems of great importance. Several of these have been mentioned from time to time in the sections devoted to zoölogy and botany. Numerous insects feed upon our growing crops, and as the acreage increases, more food is furnished for these same insects, until the damage done by them amounts to millions of

FIGURE 376. — A TYPICAL WESTERN WHEAT FIELD.

The ripe grain is being cut by a self-binding reaper. The bundles of wheat are set up into shocks or stooks of about twelve bundles each. Here they must remain until the grain dries, which takes about one week in good weather, after which it can be threshed. Photograph furnished by the Omaha Chamber of Commerce.

dollars annually. It requires all of man's skill to prevent them from destroying some crops.

Not only are animals destructive to the grains and fruits but many fungous diseases attack these same groups of plants and kill them or prevent them from producing a good yield. Again, all animals must have their food manufactured for them in just the same sense that man does; so that man

and animals are both dependent upon the green plants. There is thus a never ending interrelationship between animals and plants that requires the utmost skill of man to adjust, if human beings are to have enough food to eat, especially as our cities increase in size.

331. Food Substitutes. — Foods that can be used in place of those that we wish to save are known as food substitutes.

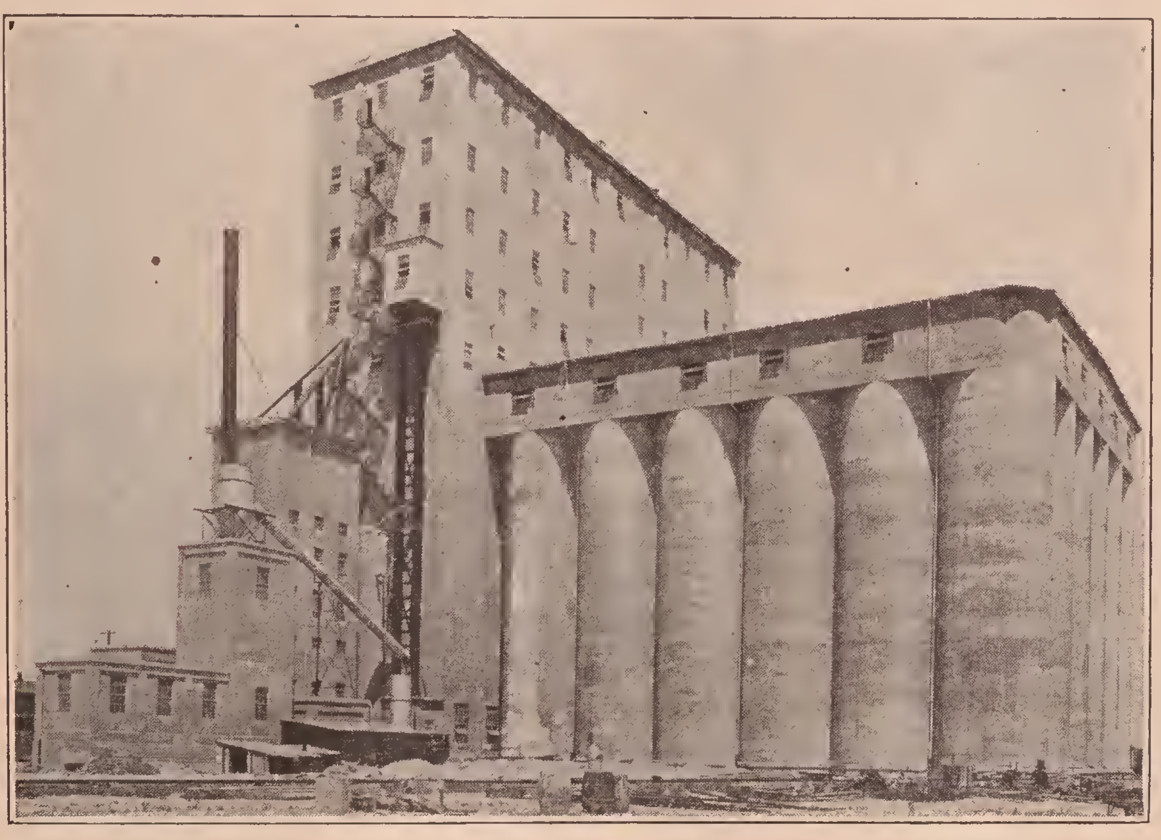

FIGURE 377. — A GRAIN ELEVATOR.

Here wheat and other cereals are stored before sending them to the mill to be ground into flour or manufactured into breakfast foods. Photograph furnished by the Omaha Chamber of Commerce.

For example, the substitutes for wheat are corn, oats, rice, barley, white and sweet potatoes; while the following can be used in place of meat: fish and other sea food, milk, cheese, eggs, nuts, legumes, and cereals. Honey, maple sirup, corn sirup, sorghum, and molasses are used in place of sugar; the substitutes for butter and lard are olive oil, corn oil, cottonseed oil, meat drippings, etc.

A great deal is being said about new foods in the study of

food substitutes, but there are really no new foods. The use of rye flour, corn meal, and such foods, while new to many people of this generation, were the most common foods with our ancestors as they pioneered and settled the land. We are in reality returning to the simpler forms of food rather than adding new foods. Find out all that you can about the

FIGURE 378. — FLOURING-MILL WHERE WHEAT IS TURNED INTO FLOUR.

One of these large mills in Minneapolis has the equipment to turn out sixteen thousand barrels of flour every twenty-four hours. Photograph furnished by the Omaha Chamber of Commerce.

different kinds of foods that were used by the early settlers in your community.

332. Food Shortage. — Keeping in mind the important fact that all foods have to be grown, it is easy to understand how there may be a food shortage. If the men who are skilled in raising food were all removed from the farms, the storehouses would in a short time be emptied of their supplies, and none would be growing to replace them. This would

result in a food shortage. With the growth of cities, more food has to be collected and transported for the use of their populations, none of whom are engaged in the production of food, but all of whom require food.

Some appreciation of the magnitude of this phase of our food problem can be gained by learning from your local dealers where the food used for one day in your home was grown. Apples and peaches are often so abundant in certain parts of New York state that large numbers of bushels are never even picked some years because the cost of labor and transportation is greater than the price that can be realized for the fruit when it is sent to market. The problem of giving all the people in our country enough to eat at reasonable prices is one of very great importance and one that you can well afford to study.

333. Increasing the Food Supply. — Whenever an increased demand is made upon the total supply of food in a nation, as was made upon the United States during the years of 1916–1919, attention is directed to two important facts: (1) that we are not using all the available foods as is noted by a study of food substitutes; and (2) that measures must be employed to increase the total production of food. To show that biological principles are the foundation for all such studies, three examples only will be given.

1. *Fish Production.* — The first food chosen to take the place of meat is fish because the food value of fish is similar to that of meat. "In America we have hardly begun to utilize our fish supply. There are said to be available nearly 70 kinds of salt-water fish and more than 30 fresh-water varieties, yet the average person knows not more than a dozen. *How many different kinds of fish have you ever eaten?* It is said that every year the fishermen of the Atlantic coast throw away about 10,000,000 pounds of fish that have a higher nutritive value than New England's famous cod. We are far behind other countries in our use of fish. Against

our 18 pounds per person each year, England used 65 pounds and Canada 57 pounds."

We should not only eat more fish but study the conditions under which fish live in order that fish may become more abundant in our fresh-water streams and lakes. Fish freshly caught is one of the food delicacies. Many of our fresh-water lakes and ponds could be made to supply an abundance of fish food if some intelligent care were taken to supply these ponds with the varieties best adapted to live in them.

Perch, pike, bass, and bullheads have a wide range of adaptation and will thrive in most of our fresh-water ponds. We have not as yet begun to utilize properly the larger streams of our country which can be made to support a great number of food-fish if the water in them is reasonably pure. Where the streams are utilized to carry away the sewage of cities and towns, the water becomes so polluted that fish cannot live in it.

2. *Improving the Varieties of Animals and Plants.* — If one compares the domesticated animals and plants in common use 20 years ago with those of to-day, many improvements are easily noted. These are due to a large number of experiments that have been carried on largely by the United States Department of Agriculture and the many state experiment stations. Here new varieties are tested and old varieties improved for the benefit of man. The net result of all these experiments has been to increase greatly the usefulness of our many domesticated animals and plants. The up-to-date farmer is thoroughly familiar with the latest discoveries in this field and often pays high prices for improved seed in order that he may obtain a larger yield. By keeping in touch with such improvements, the farmers have greatly increased the total food supply.

3. *War Gardens.* — This is a garden in a back lot or other hitherto waste land that is being used for the purpose of increasing food production. In addition to the large number

of adults that were cultivating war gardens during the years of 1917–1918, there were approximately one million and a half school children enlisted in the United States School Garden Army during the summer of 1918. It is believed that an average of one fifteenth of an acre per pupil is a conservative estimate. This would make a total of one hundred thousand acres. The average production per acre under intensive cultivation at a low estimate ought to be $50,

FIGURE 379. — WAR GARDEN.

which would give a total of fifty million dollars in value (Figure 379). Experienced truck gardeners expect to make from $1000 to $1200 per acre. How much did you make?

In addition to increasing the general food supply, there are two other reasons why the War Garden idea should be perpetuated. In the first place, the vacant lots of a city or town present a more attractive appearance when under cultivation than when occupied by weeds and rubbish. Secondly, they furnish a splendid opportunity for boys and girls to learn how many of their food plants grow and the meaning of labor.

What other ways can you suggest that will help to increase the general food supply?

334. Public Markets. — These are the places where those who raise garden truck, chickens, and other food products can bring them and the people can buy directly without paying the middleman or the retailer for his services. There is the further advantage that such foods are usually fresh. It is necessary to regulate the public markets in order that the food shall be properly prepared, and correctly weighed or measured. These markets are of great advantage to the poor people in cities, as they can get more good food at less cost than anywhere else. Is the market in your city well regulated? What are the rules governing it?

335. The Preparation of Foods. — Some foods, such as milk, fruit, and nuts, may be eaten without being cooked, but most of our food has to undergo this process before it is suitable for eating. As no two kinds of vegetables or meats are best cooked in exactly the same way, attention should be given to the preparation of food for the table. Successful cooking accomplishes three ends. (1) Changes are brought about to make the food more digestible, such as softening or dissolving it. (2) The nutritious parts are carefully saved. (3) The food is made attractive in appearance and taste, "good to eat."

Every woman who wishes to have a happy, healthy family should make a serious study of cooking. Many of the facts about the nutritive elements which foods contain, and the many changes which they undergo in cooking are found out by chemists who study them in laboratories. It is not necessary for us all to know all these facts, but a good cook follows the rules and recipes which have been made as a result of scientific laboratory studies.

To illustrate how much is involved in cooking, let us see what it means to produce a loaf of wholesome bread. Flour contains much starch, some sugar, some mineral

substances known as phosphates, a large quantity of gluten (a protein), and some bacteria (tiny plants, see Chapter XXIII) which may or may not be of value in making bread. When water is added to the flour, it becomes tough and sticky, this being a characteristic of gluten, and the most important one, so far as the making of bread is concerned. A small bit of yeast (a small plant, see Chapter XXIV) is added to the water used in making bread, and the dough is placed where it will be neither too hot nor too cold (70°–80° F.).

The yeast begins to grow rapidly, feeding on the proteins of the flour, and as the yeast grows, it acts on the sugar. A substance called *zymase* (zīm′ās), an enzyme secreted by the yeast plant, breaks the sugar up into carbon dioxide, alcohol, and a small quantity of *glycerin*. The gas tries to escape, but is held in by the sticky dough. If the yeast plant is well distributed, the gas collects in many small bubbles, and the loaf is fine-grained. The alcohol keeps other plants from growing there, and also helps to soften the gluten.

When the loaf is put into the oven, the heat kills the yeast plant, drives off the carbon dioxide, and causes the alcohol to evaporate. The heat changes the gluten into a substance more easily digested and of a more pleasant taste. In "salt rising" bread, bacteria from the air, instead of yeast cells, form the gas which makes the bread light. When a batch of bread "sours," it is usually because harmful bacteria get into the dough and grow more rapidly than the yeast plants. Sometimes other kinds of yeasts than the helpful ones employed in bread-making accidentally get into the batch of bread and it spoils as a result.

During the war we used substitutes in our wheat flour with the result that many good cooks were not able to make as good bread as usual. This was not the fault of the cooks but was due to the following facts. Although corn, barley, and wheat flour contain nearly equal amounts of similar proteins, the proteins of corn, barley, and rye do not react

the same to water and the acids produced during fermentation. The dough made from these substitute flours does not hold together and is not so distensible as that made from wheat flour. These unfavorable conditions of the dough can be improved by adding a small amount of what is known as the "proteins of serum," a special preparation that is in the form of a dry powder.

336. Adulteration of Foods. — Foods are adulterated either by subtracting some of the nutritious parts and substituting less valuable parts, or by adding materials which cannot act as a food.

The food formerly subject to the most adulteration was milk. This adulteration was accomplished by adding water to make the milk go farther when being measured out, and adding *formalin* (fôr′mȧ-lĭn) to make it keep sweet.

For a time many of the cereals were adulterated with sawdust, peanut shucks, or bran. Many of the special foods put up in packages used to be adulterated, and it would require a long description to enumerate all that have been found unsatisfactory for food by the Department of Agriculture.

337. Pure Food Laws. — The Food and Drugs Act passed by the United States Congress on June 30, 1906, requires of manufacturers of foods and drugs that a definite statement be made as to their composition. A number of regulations and rules have been issued from time to time. The last was issued June 15, 1917, and related to the marking of the quantity of food in packages. Here we find that when food is in package form, it must be plainly marked in terms of weight, measure, or numerical count on the outside of the package. The quantity of the contents so marked shall be the amount of food in the package.

This Pure Food and Drugs Act established high standards for many of the common and necessary foods of man. Before its adoption there was no standard for the manufacturers

to go by. One of the reasons why it has been so valuable is because it includes so many different products. Food standards have been established for the following: meats, meat extracts, milk, cream, butter, cheese, ice cream, grains, meals, flour, fruits, vegetables, flavoring extracts, of which there are twenty-four, tea, coffee, cocoa, vinegar, and salt.

The wide range of patent medicines and drugs comes under the influence of this act and we can now read their composition on the label. This is a great protection against misbranding and cheating.

338. Indigestion. — Few children that have an opportunity to romp and play out-of-doors and have plenty of simple and plain food ever experience any ill feeling in the digestive canal. However, as children grow older, exercise less, and eat richer food, they may suffer much inconvenience from indigestion.

Indigestion is a condition which rarely extends to all parts of the digestive canal; it is located either in the stomach or in the small intestine. This may indicate that certain kinds of food are not properly digested. Indigestion may be caused by eating the wrong kinds of foods or by overloading the stomach. If the food is chewed thoroughly, the appetite is usually a safe guide as to the amount needed by the body. Moreover, food thoroughly chewed is more easily acted upon by the digestive fluids.

To some people certain foods are indigestible at all times, while other foods are indigestible only at special times. We should learn to understand our bodies in this particular. Some of the causes of indigestion are: lack of sufficient regular exercise, too much rich food, and the failure to drink enough water.

Students and professional men use their brains more than their muscles, but they require protein to repair nerve waste just as laborers require proteins to feed their tired muscles. Unless students and professional men exercise

their muscles, they do not feel vigorous and eager for their work. On the other hand, unless the laboring men exercise their brains, they do not do their work as well as they might. The proper amount of exercise varies with the individual. The best way to prevent indigestion is to have regular habits of eating and exercising.

There are in the market many tablets and remedies for indigestion, which may, for example, contain pepsin and pancreatin. Now we know that these substances when found in the pancreatic fluid act in an alkaline medium. As these tablets must first pass into the stomach, which is an acid medium, the action of the pancreatin is probably destroyed long before the remedy reaches the intestine where it would naturally act. This means that such tablets are largely useless and it is one of the reasons why many doctors believe that digestive tablets are doing more to cause indigestion than they do to help it. There are only a few commercial tablets made which act on the undigested foods of the intestine. No medicine, in fact, can give permanent relief to indigestion. Predigested foods, an attempt to relieve indigestion, serve a useful purpose in cases of sickness, but in our regular life, should be used sparingly because they do not give the digestive organs the proper amount of work to do.

339. Effect of Alcohol on Digestion. — Alcohol taken into the digestive tube is closely related to the question of indigestion. The lining (mucous membrane) of the stomach and intestine is delicate and tender, and it contains thousands of cells which secrete the gastric juice, and many more thousands that help to digest the food. When alcohol comes in contact with these delicate cells, it prevents them from doing their normal work. The result is that food is not properly digested.

Indigestion Disguised by Alcohol but Not Cured. — It is a serious error to regard alcohol as a genuine remedy for

indigestion or abdominal pain. It is true the sense of pain is sometimes abolished by alcohol, and as a result of this many a man believes that alcohol aids his digestion, whereas it merely exerts a numbing effect on the stomach nerves, and his indigestion is disguised rather than removed. In fact, instead of being cured the mischief is increased since digestion is retarded. Some digestive medicines contain enough alcohol to be injurious. Alcoholic drinks taken with meals make the food hard to digest because the alcohol makes the food tough.

SUMMARY

Man has a definite set of digestive organs that are more highly developed than those of any other animal. These digestive organs prepare proteins, carbohydrates, and fats so that they pass into the blood. The blood is forced by the heart through definite blood vessels. The study of food is important because we require food in order to live. The cost of food and the amount needed are problems that science is helping to solve.

QUESTIONS

What do man and other animals require in order to grow? Name the kinds of foods. What is the value of protein? Of carbohydrates? What is a calorie? What are food substitutes? Name several ways in which the supply of food can be increased. What does cooking do to foods? Why is this important? What is digestion? What is indigestion? Absorption? How are the cells of the body fed?

CHAPTER XXXII

MOVEMENT

In the introduction to biology and man, we have seen how man came to live in all parts of the world in well made houses to protect him from the cold and rain. In this respect he is superior although similar to all other animals. As we studied his use of food, there was seen also to be a fundamental similarity between man and animals. Now as we take up the next life process of movement the same relationship will appear.

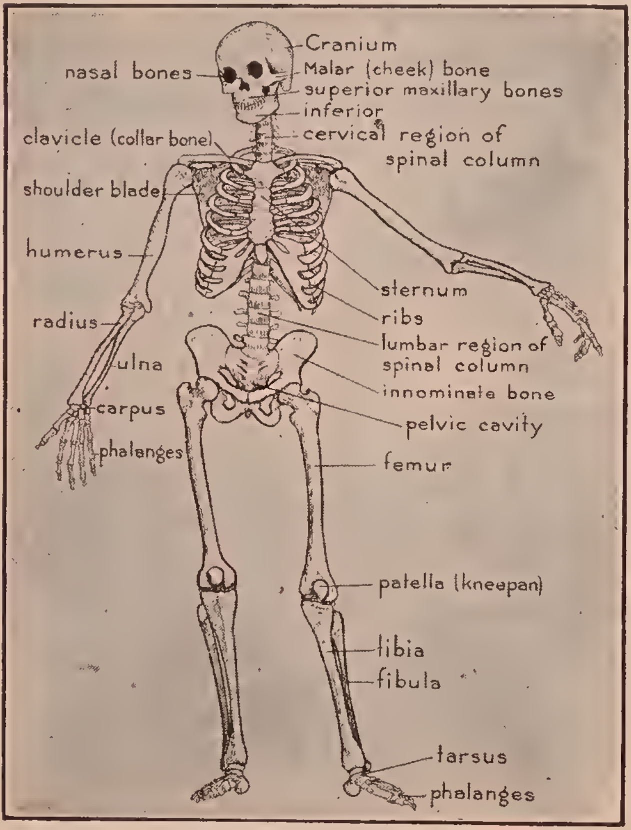

FIGURE 380. — SKELETON.

We usually think of man as walking or running, and it is only when we witness an acrobatic performance that the wide range of movements possible in man is realized. That man can do so many more things with his body than any other animal is due to the greater development of his nervous system. The structures by means of which he moves and which are described in this chapter are the muscles and the skeleton.

340. Skeleton and Muscles. — Muscles which serve to move the body cover and protect the skeleton of man. The

more delicate organs of the body are protected further — the heart and lungs by the ribs, and the brain by the cranium. The skeleton and muscles of man are similar to the corresponding parts in the frog and the dog. Certain technical differences are noted by anatomists, but in general plan or structure and in their functions, the skeleton and muscles are alike in all the higher animals.

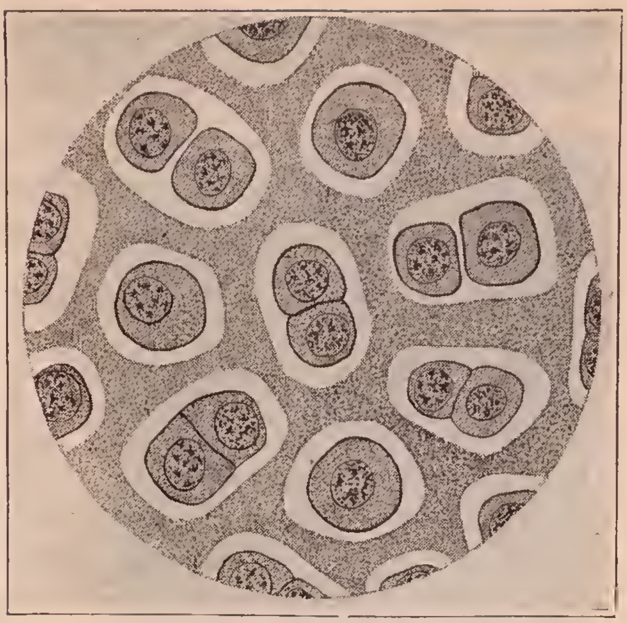

FIGURE 381. — CARTILAGE.

Note that the living cells are separated by spaces represented by small dots.

341. The Skeleton. — Unlike the rest of the body the skeleton proper is hard. It consists of bone and a comparatively soft substance known as *cartilage,* or gristle. There are cells in the bones just as there are cells in the liver, the muscles, and in the nervous system. So, like the other parts of the body, the bones grow because the individual cells are supplied with food from the blood.

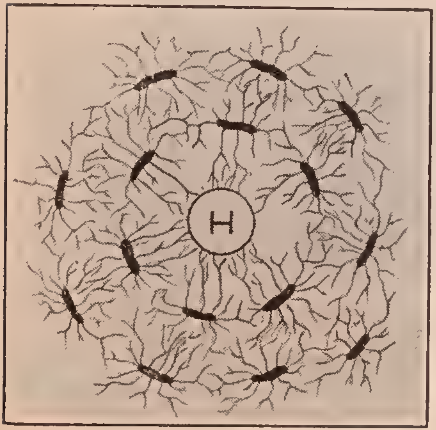

FIGURE 382. — DIAGRAM TO SHOW THE STRUCTURE OF BONE.

The large circle. H, is a branch of the Haversian canal where the blood vessels are found. The spaces between the lines and oval black masses is bone.

Cartilage occurs near the ends of the bones, in the ear, and in the nose. It is especially prominent in the wrists and ankles of children. Therefore children should not be lifted by their hands or allowed to stand until a certain amount of bone has taken the place of this soft cartilage. This is readily appreciated when one examines an X-ray of the wrist of a child, which is almost entirely composed of soft cartilage

while the adult wrist has well-formed bones. The transition from soft cartilage to hard bone is due to the formation of mineral matter that takes the place of the cartilage.

The erect position of man gives to his skeleton important characteristics which the skeletons of other animals do not possess. Among these may be mentioned the curves

FIGURE 383. — X-RAY OF HAND OF CHILD.

The bones in the wrist are forming. Between the joints of the fingers are seen small bones that later unite with the bones of the hand. Compare with Figure 384.

FIGURE 384. — X-RAY OF HAND OF ADULT.

What changes have taken place since childhood?

in the spinal column, the large hip bones, and the heel and arch of the foot.

342. Joints. — The numerous bones in the skeleton allow the body to move although giving a certain amount of rigidity and permanence of shape. Wherever two bones meet and allow movement, the term joint or, more technically, articulation, is applicable. The joints are divided into three classes: (1) Immovable joints (sutures), found in the skull of the

adult. The bones of the skull do not become firmly united until the head has reached full size, after which no movement takes place between these bones; (2) movable joints, such as the ball-and-socket joint in the shoulder and hip and the hinge joint in the elbow, wrist, knee, and ankle; (3) the mixed joints of the spinal column which allow only a limited movement.

FIGURE 385.—X-RAY OF DISLOCATED FINGER.

FIGURE 386.—X-RAY OF BROKEN FEMUR.

The movable joints are bound closely together by strong bands of connective tissue. These bands are called ligaments. The tearing or stretching of these ligaments is called a sprain.

343. Broken Bones. — When the bones of a limb are broken, the physician sets them, *i.e.* places the broken ends together, and puts splints on the limb to keep the parts from slipping until the new bone has formed (grown) and

FIGURE 387.— X-RAY OF THE SAME BONE AFTER HEALING.

Notice the large "callus" of newly formed bone which makes this bone stronger than before it was broken.

hardened. In Figure 386 is shown an X-ray photograph of a recently broken femur. In Figure 387 the same bone is shown. A large "callus" of new bone has formed around the broken ends, which gradually hardens, making this part of the bone stronger than ever.

344. Structure of Bone. — One of the long bones from the arm or leg illustrates best the several parts. There is the long shaft with knobs on each end. These enlargements are the heads of the bone. The outer surface is covered with a tough membrane. If such a bone is sawed lengthwise, the following additional parts can be recognized: the long central cavity of the shaft filled with marrow; the hard bone of the shaft; the spongy bone toward each end; and the thin layer of cartilage covering each head.

LABORATORY STUDY

Study the skeleton, and examine long, flat, and irregular bones. How is the bone modified to do its work?

STUDENT REPORT

Make a report on the skeletal structures of animals as follows:

External

	Absent	Jointed	Not Jointed	Horny	Bony	Internal
Paramecium .						
Crayfish . . .						
Clam						
Frog						
Man, etc. . .						

345. Muscles. — The muscles are the lean parts of the flesh of animals. They are covered by the skin and are usually dark in color. Birds are an exception, for their breast meat is generally white. Muscles are of two kinds: *voluntary* (governed by the will), such as those which we use in

walking, or in moving the arms, Figure 388; *involuntary*, such as those which move the food along the digestive tract or assist in breathing.

The voluntary muscles consist of many long muscle cells (fibers) bound together by connective tissue into a distinct bundle. Usually the muscle bundle is attached at each end to the bones through the tendon of connective tissue. A single muscle moves the arm in one direction only, and in order to lift the arm from the desk to the head, for instance, several muscles must act together.

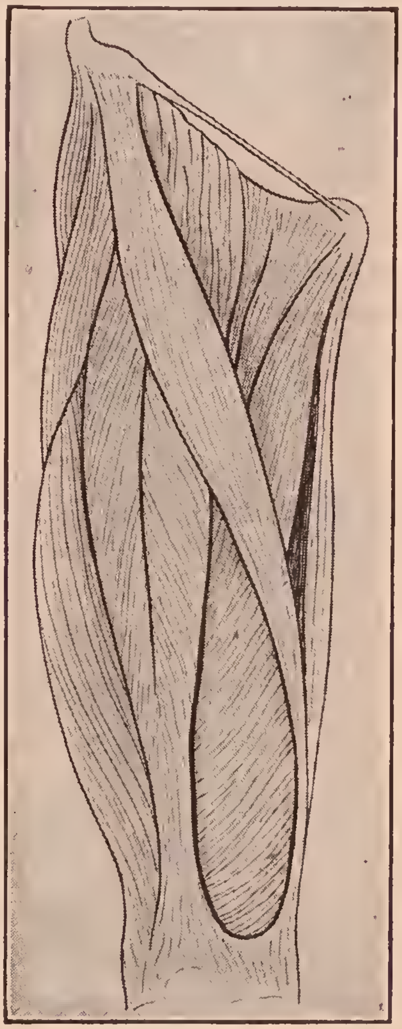

FIGURE 388. — MUSCLES OF UPPER LEG.

Note how they are arranged in bundles which is an adaptation that enables the leg to be moved in various directions.

The cells of the involuntary muscles are unlike the cells of the voluntary muscles. Involuntary muscle cells occur in layers in the walls of the digestive tube, blood vessels, the bladder, and the like, and they are not under the control of the will.

The muscular tissue of the heart has characteristics of both the voluntary and involuntary muscles, so that it may almost be said to belong to a special class.

346. Importance of the Muscles. — When we remember that 40 per cent of the weight of the human body is in the muscles alone and that one fourth of the blood is found in these same muscles, their importance is appreciated. But this great mass of tissue so richly supplied with blood is solely for the purpose of producing movement. In addition to the movements that we are accustomed to see, such as the motion of the arms, legs, and the head, there is

the continued beating of the heart, the rhythmical contractions of the stomach and intestines, as well as movement in other organs. To all these should be added the wide range of movements in facial expressions. To accomplish these varied motions man uses more than five hundred muscles.

FIGURE 389. — VOLUNTARY MUSCLE CELLS.

Showing how the cells are bound together with connective tissue. At the end of the muscle, the cells of the connective tissue form the tendon.

347. Action of a Voluntary Muscle. — By placing the hand on the front of the forearm and raising the hand toward the shoulder, the muscle under the hand becomes shorter, thicker, and firmer. At the lower end of this muscle, a strong cord can be felt as the forearm is lowered. This cord is the tendon that attaches the muscle to one of the bones of the forearm. The upper end of the muscle is covered by other muscles, but we know that it is attached to the shoulder blade by two tendons. This muscle is the biceps, and like all other arm and leg muscles consists of a central part, the belly. It has its origin on the shoulder blade by two tendons and is inserted on the radius bone by one tendon. When a voluntary muscle produces motion, the two ends of the muscle are drawn closer together and the belly becomes shorter, thicker, and firmer. The living muscle cells are the only parts that undergo any change in shape, while the living cells in the connective tissue sheaths and in the tendons remain unchanged.

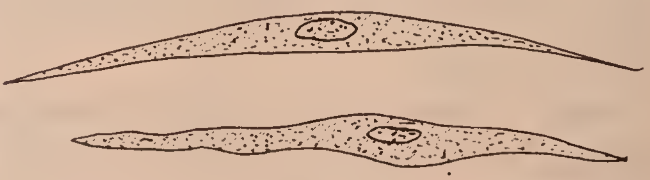

FIGURE 390. — INVOLUNTARY MUSCLE CELLS.

348. Nerve and Blood Supply of Muscles. — The muscles are richly supplied with numerous large and minute blood vessels and it is the blood that gives the deep red color to muscles. In recent years scientists have discovered that each muscle fiber is supplied with a fine branch of the main

nerve that enters the muscle. This important fact enables us to understand how the nervous system is able to control the actions of our muscles.

349. Food of Muscles. — The blood flowing through the muscles carries food to the muscle cells. The most important of the food substances used in the contraction of a muscle is grape sugar, or glucose. This sugar is formed in the body in digestion from starch and cane sugar. *Glycogen*, the stored-up sugar in the liver, is also used to furnish energy in contraction, but not until it has been transformed into sugar. A small amount of fat is present in muscles and may be used up during their contraction. Under ordinary circumstances the protein foods do not furnish energy for contraction, but are used to repair the actual wastes that take place in the muscle cells as they do work.

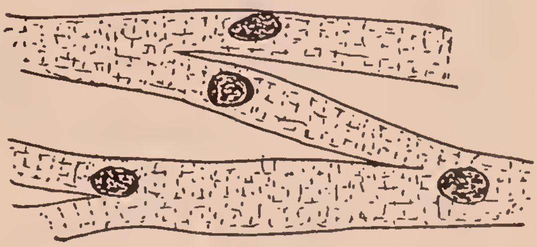

FIGURE 391. — HEART MUSCLE CELLS.

350. Fatigue of Muscles. — After you have played hard for a time, you become tired and want to rest. You are tired or, to express it more scientifically, your muscles are fatigued. When you are taking your physical exercises, some of the movements make your arms ache, and you do not do them in good form. You are using muscles that do not get much exercise and they become quickly fatigued. You may continue to move your arm until it is impossible to move it any longer. In such cases of extreme fatigue not only are the muscles tired but also the nerve cells. Two things are involved in the fatigue process of a muscle: first, there is the using up of the food energy necessary for muscular contraction; and secondly, there is the accumulation of waste substances produced by the activity of the muscles.

351. Recovery from Fatigue of Muscles. — It is difficult to separate entirely a consideration of the muscles from the nervous system, as already explained, but some facts indicate

in part what probably happens in the muscles as they are again made fit to do work. If the exhausted soldier is given a small amount of sugar while on the march, his fatigue is lessened. This is because sugar is quickly absorbed and is used by the muscles as a source of energy for contraction. This indicates that food will restore muscles. A second factor in relieving fatigue is rest, which gives the muscle cells time to recuperate by gradually building up the muscle protoplasm, and removing wastes. As the energy required for the action of a muscle is mainly in the muscle protoplasm, there are changes that take place in it. Not all the energy can be used in the contraction of the muscle, and what remains is a waste substance that has to be removed. The removal of this waste is a large factor in relieving fatigue in muscles.

352. Physical Training. — We are now in possession of the facts that enable us to understand the reason for physical training and some of the benefits to be derived from it. It is true that walking and running are forms of exercise, but they are both limited to but a part of the more than 500 muscles of our body. Every morning our soldiers and sailors are put through the "setting-up" exercises. These are similar to those that you have in school each day except that there are more of them. These exercises aim to give every muscle in the body a chance to do its proper work. People unaccustomed to a full set of setting-up exercises find themselves lame and sore after the first few times. This is because they exerted muscles that had been unused for a long time and these muscles are not so strong as they ought to be. In a short time this lameness disappears and the morning exercises then give vigor and zest to the body.

These exercises thus serve to keep the bulk of our body, our muscles, in a healthy state. Such a condition has an important bearing upon our ability to do good work with our brains because the mind works best when the rest of the

body feels fit and full of energy. The physical examination of the drafted men in the United States during 1917–1918 indicates that we have not paid enough attention to keeping our bodies in physical condition and when the opportunity came for many to render one of the greatest services that one can for his country, they were found to be physically unfit. What man can take pride in being physically unfit to serve his country? It is our duty to take our physical exercises seriously in order that we make our bodies as strong and vigorous as possible.

SUMMARY

Man is able to move about as other animals. This he does by means of his muscles and skeleton, under the direction of the nervous system. The skeleton is covered by muscles and skin. Bones grow and are fed just like muscles or any other tissue in the body. The bones of the skeleton move by means of joints which are held in place by ligaments. Bones grow new bone, as is seen in the broken femur. There is a definite plan of structure to all bones. The muscles are the flesh covered by the skin. The muscles are both voluntary and involuntary. Muscles are important both in the total weight of the body and in the numerous movements that they produce. Each muscle causes movement through the action of its individual cells, which are supplied by nerves and blood vessels. The muscle protoplasm is supplied with food for contraction purposes and food to repair the wastes. Muscles become fatigued and require food, rest, and the removal of wastes in order to recover from this fatigue. Physical training is valuable in helping to develop properly all the muscles of the body, in keeping the body well, and in making it the best body possible.

QUESTIONS

How does the skeleton of man compare with that of the crayfish? How do bones grow? Why do they grow? Where is there the most

cartilage in our skeletons? What are joints? What is a sprain? How do broken bones heal? How does muscle differ from bone? How many kinds of muscles are there? What is the work of each? Why are muscles important? What is the relation of the nervous system to muscles? What is the importance of the blood vessels to the muscles? Explain how the different foods are used by muscles. What is the value of physical training?

CHAPTER XXXIII

RESPIRATION AND EXCRETION

In this chapter are combined the two fundamental life processes of respiration and excretion together with a description of the more important organs that are necessary to the performance of these processes. Two important practical problems are suggested as a result of a discussion of these topics. The problem of leather naturally follows the description of the skin and the problem of sewage follows the general subject of excretion.

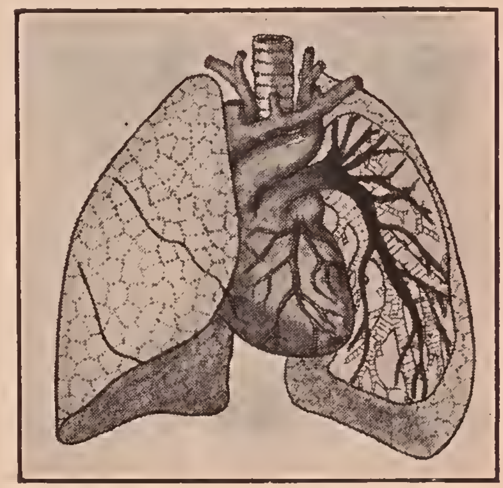

FIGURE 392. — THE LUNGS AND HEART.

Note the branches of the bronchus and blood vessels on the right side.

353. *Respiration* is the life process in which oxygen is used in the cells of the bodies of plants and animals, and carbon dioxide eliminated from them. All animals carry on respiration, and in all the process is alike, although the various animals use different structures to secure the interchange of oxygen and carbon dioxide. The hydra and earthworm use the entire surface of the body in this process; the fish has special organs, the gills, while the frog and man have lungs.

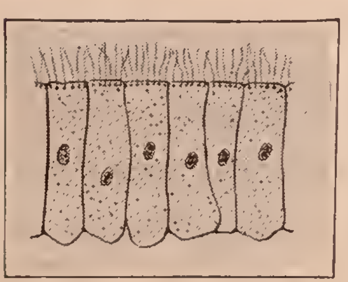

FIGURE 393. — CILIATED EPITHELIUM.

Such cells line our bronchial tubes. Explain their work.

Student Report on Respiration

	Get Oxygen		Get Rid of Carbon Dioxide		Breathe Through				
	Water	Air	Water	Air	Skin	Gill	Lung	Air Tubes	Leaves
Amœba									
Crayfish									
Fly									
Clam									
Toad									
Bird									
Man									
Bean									
Yeast									

Organs of Respiration in Man. — Air enters the nose and passes into the windpipe or trachea (trā'kē-ȧ). The opening into the windpipe is covered by the *epiglottis* (Greek, *epi*, upon; *glotta*, tongue), which is raised during breathing and closed when food is swallowed. The windpipe divides into two branches, one entering each lung. Each branch is called a *bronchus.* The windpipe and bronchi are the air passages which carry air to the lungs. These passages are kept open by numerous stiff cartilage rings, which, in the trachea, are not entirely complete on the side of the esophagus, and in the smaller tubes even less so.

On entering the lung each bronchus divides into branches which in turn branch out again and again, until the entire lung is penetrated in all its parts by these passages. Finally each branch ends in a small pouchlike sac called an air cell. The walls of the air cells are thin, and the cells themselves are surrounded by minute branches of the blood vessels. It is estimated that the highly folded condition of the walls of the bronchi make a surface larger than the entire surface of the body. All these thin walls of the lungs and blood

vessels are adapted to the passage of oxygen into the blood.

The lungs of man, then, consist of two large bronchial air tubes, many branches of the bronchi, air cells, blood vessels, and a few nerves, all bound up into two definite bodies (Figure 392).

The voice box or larynx (lăr′ĭnks) is found just below the opening into the windpipe and is called "Adam's apple." The larynx is formed by several large pieces of cartilage

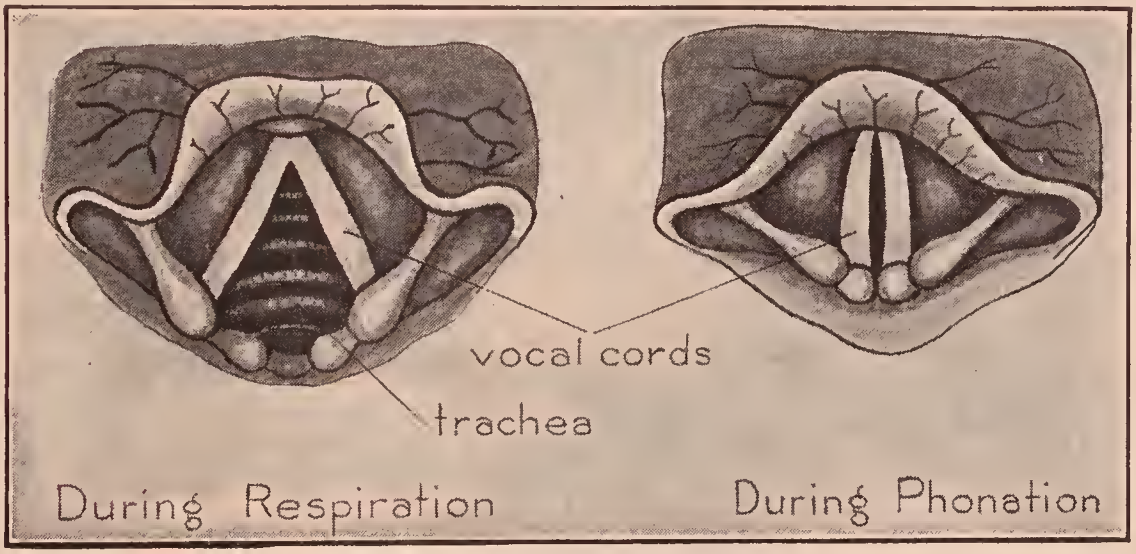

FIGURE 394. — VOICE BOX OR LARYNX.

lined with a mucous membrane. On the inside of the larynx project two folds of elastic tissue which are called the *vocal cords*.

354. Breathing. — The lungs are elastic and can be squeezed like a sponge. *Inspiration* is the term applied to the taking of air into the lungs, and *expiration* to the forcing out of air. When air is drawn into the lungs, the chest expands, and the *diaphragm* (Figure 395), the horizontal muscle which divides the lung cavity from the abdomen, is drawn down. Thus the chest cavity is enlarged and air is sucked into the lungs. In expiration the air passes out gently.

When we breathe naturally, only a small part of the air in the lungs is exchanged at each inspiration and expiration,

but by breathing deeply a few times we can remove the larger part of the air from the lungs and replace it with fresh air.

The natural rate of breathing is about eighteen times a minute, but the rate is higher in persons with a small lung capacity. Exercise increases the rate of breathing. Explain why exercise out-of-doors is better for us than that taken indoors.

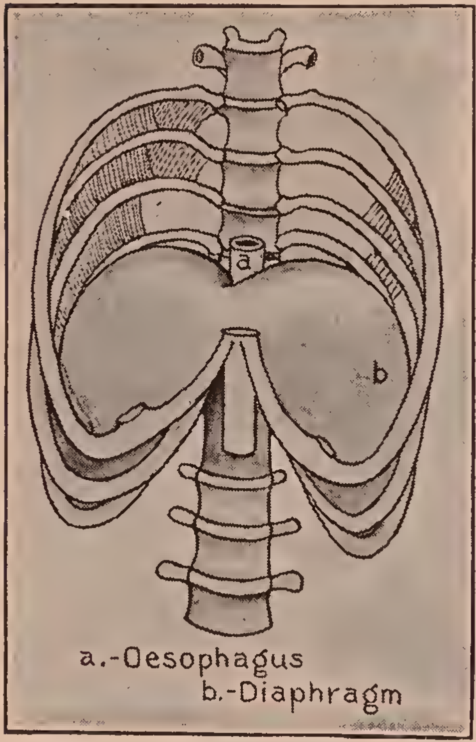

FIGURE 395.— DIAGRAM TO SHOW THE RELATION OF THE DIAPHRAGM TO THE RIBS.

Between the ribs are shown some of the intercostal muscles that assist in respiration.

All the air passages are lined with cells bearing numerous cilia (Figure 393), and these cilia are constantly in motion. Their work is to carry toward the mouth the particles of dust and other foreign materials brought in by the air. This foreign matter is removed when we cough or clear our throats. Explain why clean air is better for us than foul air.

The purpose of respiration is to take the air, rich in oxygen, into the lungs, where the oxygen passes into the blood as the capillaries penetrate the walls of the lungs, and to give off the waste carbonic acid gas that has come from the cells of the body. Thus respiration is a twofold process, the supplying of the living cells of the body with oxygen and the removal of wastes from the blood. The air that is inhaled contains a small amount of carbonic acid gas, but the proportion is much smaller than in the exhaled air. It is well to keep in mind that green plants are constantly, during the daytime, using carbonic acid gas in manufacturing starchy foods and giving off oxygen so that the air is being made better for animals and man to breathe, while at the same time

these green plants are storing up food for animals, including man.

Ventilation. — Associated with the question of breathing is the problem of supplying our homes with fresh, pure air. Every one feels better after a walk in the open air. How to have plenty of fresh air in our rooms is a difficult problem. One of the difficulties is to get the air down to the breathing line and not stir up the dust on the floor. Figures 396 and 397 show the best plans for ventilating a room. They are adapted to the two common methods of heating, hot air and steam or hot water. They show the course taken by the currents of fresh air entering the room at night with the window open, and in the daytime with it shut.

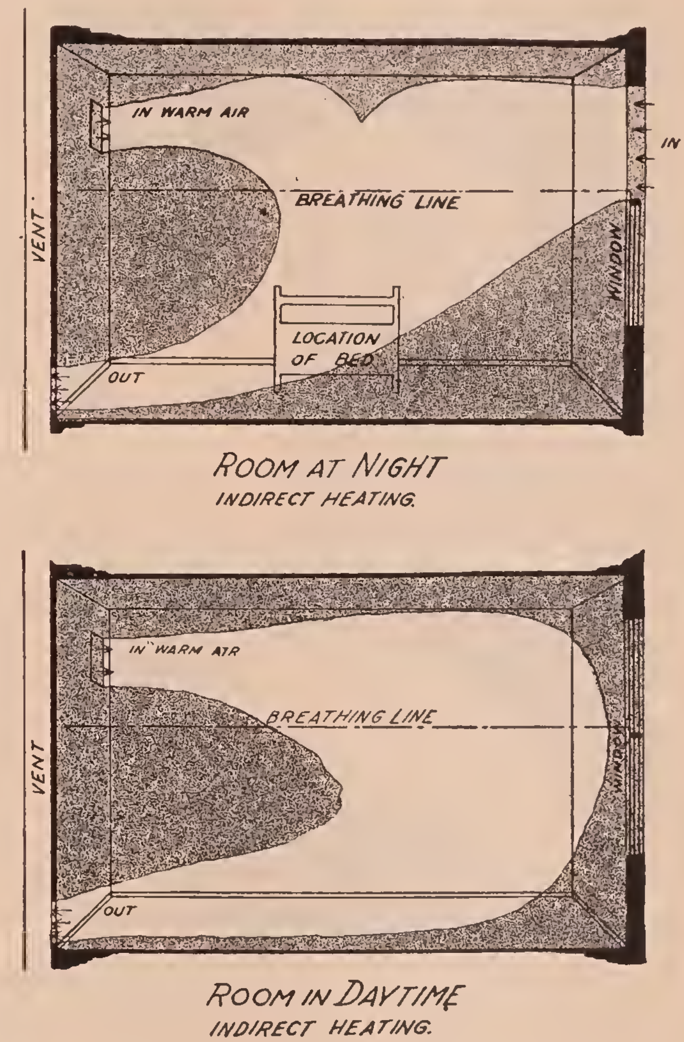

FIGURE 396. — HOT-AIR HEATING.
By Earl Hallenbeck.

Exercise. — Even if the home is furnished with fresh air, we should observe good habits of breathing. When we walk out-of-doors, we should take plenty of fresh air into our lungs in a series of deep breaths. All young people should take exercise in the open air, because such exercise develops all the organs and makes them strong. Thus the whole body becomes more robust and better able to withstand disease and to do its work.

Suffocation. — When the body is deprived of a sufficient

supply of oxygen, suffocation results. This is what happens in drowning or when the windpipe becomes closed.

In many cases a person who is suffocating may be saved through artificial respiration. This is the name given to a series of movements which are used to restore natural breathing. The simplest method is to place the patient on his back, with the head lower than the hips. Then raise the arms upward and outward until they come together above the head. This movement enlarges the chest cavity and helps to draw air into the lungs. The air is forced out of the lungs by bringing the arms back to the side of the body and pressing gently against the sides of the chest. This series of movements should be repeated gently every few seconds, and may have to be continued for two or three hours before natural breathing is restored.

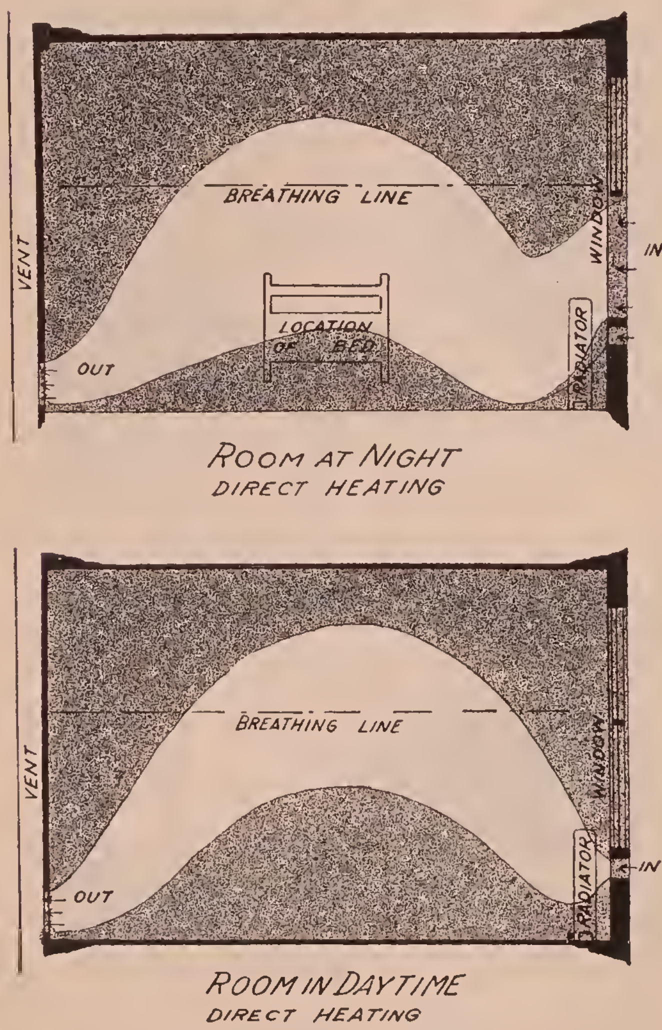

FIGURE 397. — STEAM HEATING.
By Earl Hallenbeck.

Diseases of the Respiratory Tract. — The most common of these diseases is a cold located in the nose and throat. The nasal passages become clogged with mucus which contains many germs. These germs are widely distributed in sneezing.

Diphtheria is a germ disease which is located in the throat and nose. For many years diphtheria was one of

the most deadly of our diseases, but through the use of the diphtheria antitoxin the danger has been greatly reduced.

Bronchitis and pneumonia are germ diseases located in the bronchial tubes of the lungs. Pneumonia is a frequent cause of death among aged people.

Tuberculosis of the throat and lungs is a widely distributed disease which causes many deaths each year. See page 489.

Adenoids are the result of an enlargement of the pharyngeal tonsil. The commonest result is the stopping of the nasal passage. Almost all mouth-breathing children have adenoids. These should be removed not only because they prevent the natural use of the nasal passage but because they often cause deafness.

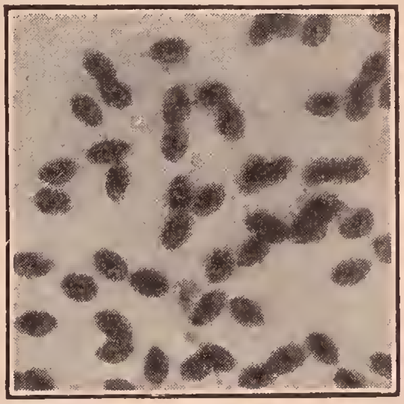

FIGURE 398. — PHOTOMICROGRAPH OF BLOOD OF FROG.

The minute black spot in each corpuscle is the nucleus. The nucleus is absent in human red blood corpuscles.

355. Blood. — The blood is the fluid which circulates through the heart, arteries, and veins, supplying nutritive material to all parts of the body. Blood is made up of a fluid (plasma) which contains cells or corpuscles (Latin, *corpusculum*, little body). The blood cells or corpuscles are of two kinds, red and white.

The red corpuscles are colored with a substance called *hæmoglobin* (hē-mō-glō′bĭn: Greek, *haima*, blood; *globus*, ball). When a few of these corpuscles are examined through a microscope, they appear yellowish instead of red; but when a large number of them are seen in a mass, the red color is apparent. When the red cells are first formed, they have a nucleus which gradually disappears. As a result, the mature red corpuscles, unlike all the other cells we have studied thus far, have no nucleus. Red corpuscles are about $\frac{1}{3200}$ of an inch in diameter and $\frac{1}{12400}$ of an inch thick.

The red corpuscles carry oxygen from the lungs to the

cells of the body. As soon as the oxygen in the respired air enters the blood, it unites chemically with the hæmoglobin contained within the red blood corpuscles. Here it remains until it reaches cells that are deficient in oxygen, when it passes from the blood by osmosis to such cells. These cells take the oxygen and use it in the process of oxidation, which goes on continuously in every living cell. A good supply of red blood corpuscles is, therefore, necessary, if the cells of the body are to have a sufficient supply of oxygen. The feeding of the cells with oxygen is one part of respiration.

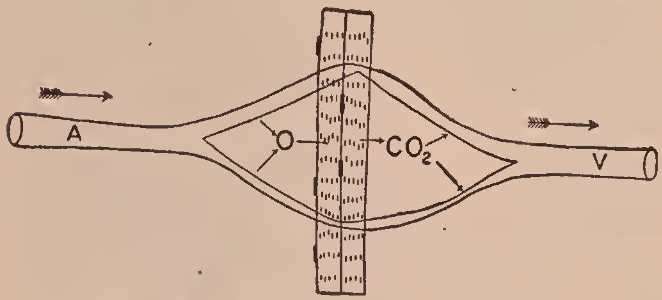

FIGURE 399.

As the blood flows through the capillaries which are found in all voluntary muscles, for example, oxygen and other food products are given off to the muscle cells, and carbon dioxide and other waste substances pass off from these same muscle cells into the capillaries on the way into the veins.

At the same time that oxygen is received from the blood by the body cells, carbon dioxide is given off. Again osmosis explains the method of this transfer. Most of the carbon dioxide is carried by the plasma, although some of it unites with the hæmoglobin.

White blood corpuscles are much like the amœba in that they are colorless and can change their form. They move about in the body and often leave the blood vessels and collect at one place to aid the body in destroying disease germs. The white blood cells eat these disease germs in just the same manner that the amœba or paramecium eats bacteria.

The blood plasma is straw-colored and varies in composition from day to day, and hour to hour. It contains the foods on their way to the cells and waste products on their way to the kidneys, lungs, or skin.

The volume of blood in the average person is about six quarts.

356. Clotting of Blood. — When the blood is exposed to the air it forms a clot. This is a peculiarity of blood alone. If it were not for this property of blood, animals would bleed to death from even a slight cut. In some warm blooded animals, the blood clots more quickly than in man. Man is able by pressing upon the blood vessels or by tying them to assist the process of clotting and prevent hemorrhage (hĕm′ôr-rāg). Naturally the blood does not clot except when exposed to the air when fibrin threads are formed from the fibrinogen (fī-brĭn′ō-jĕn) of the plasma of the blood. These threads hold the red and white corpuscles. After a short time the whole mass shrinks, squeezing out the fluid part of the blood, and the semi-fluid mass that remains is the clot.

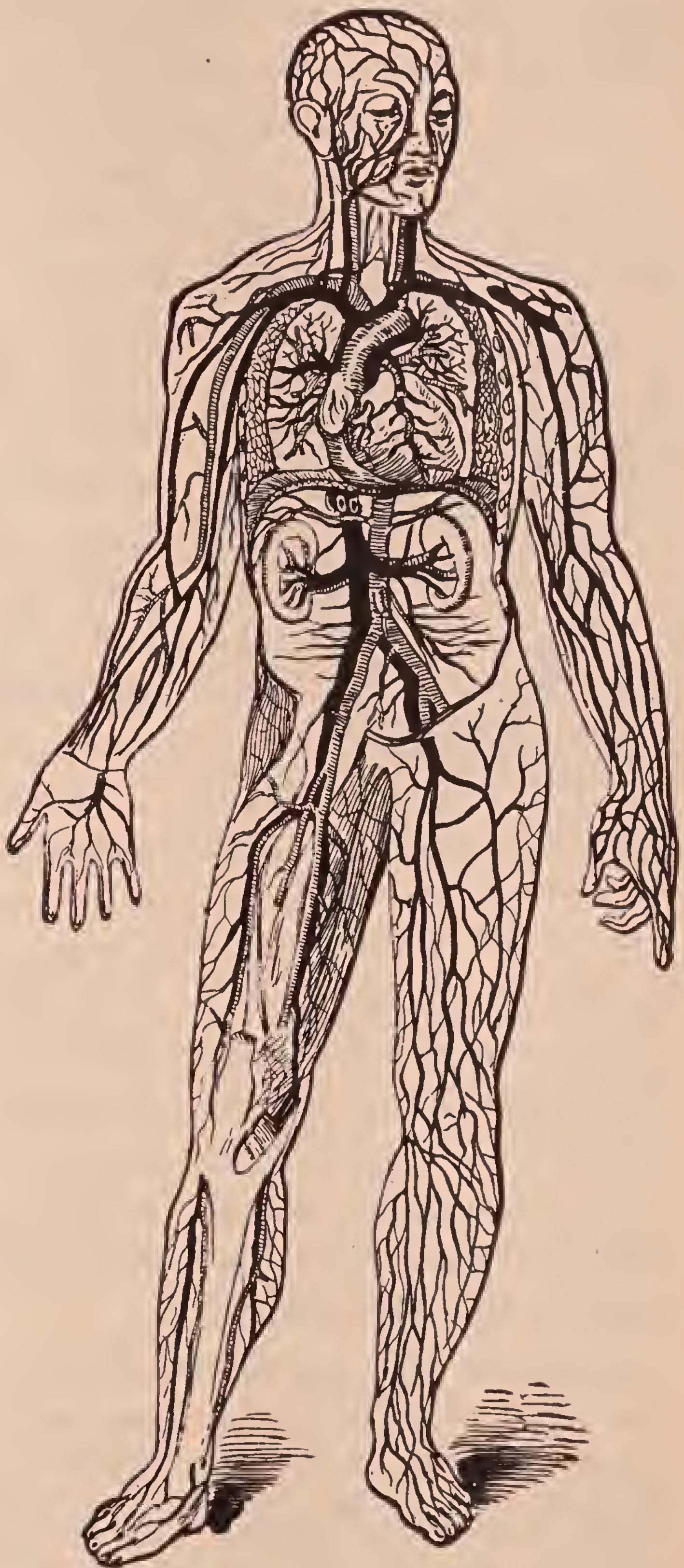

FIGURE 400. — ORGANS OF CIRCULATION.
Veins, black; arteries, with transverse lines. Left side of figure shows superficial vessels, while right side shows deeper vessels.

357. Heart and Blood Vessels. — The blood is carried from the heart

to all the cells of the body and back to the heart again and again. The heart serves as a pump to force the blood along. The heart is about the size of the fist and has strong muscular walls. In a healthy person, it contracts regularly about seventy times a minute. It is obvious, therefore, that the work which the heart does is very great.[1]

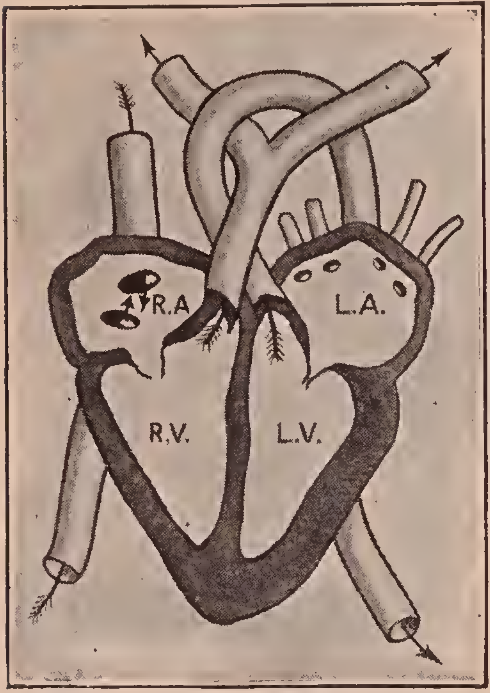

FIGURE 401. — HEART.

R. V., right ventricle; *L. V.*, left ventricle; *R. A.*, right auricle; *L. A.*, left auricle. The arrows indicate the direction that the blood takes. Describe its course through the heart.

The heart is located in the *thoracic*, or chest cavity, a little to the left side and between the lungs. It is a cone-shaped organ, inclosed in a membranous bag called *pericardium* (pĕr-ĭ-kär′dĭ-ūm: Greek, *peri*, around; *cardia*, heart).

The heart is divided by a wall into right and left chambers. A nearly complete cross partition divides each side into upper chambers, the *auricles*, and the lower ones, the *ventricles*. The opening between an auricle and a ventricle is guarded by a valve, which is partly membranous and partly muscular. The auricles receive blood from the veins, while the ventricles force blood into the arteries.

Artery is the name given to the blood vessels which carry

[1] "The work the heart does during the day is about equal to the energy expended by man in climbing to the top of a mountain 3600 feet high. Assuming that the man weighs about 150 pounds, this would be equal to an amount of energy sufficient to lift 90 tons to a height of three feet. The work of the left side is greater than that of the right, since the former has to drive the blood all over the body, while the latter has only to force it to the lungs which are near by. For this reason the muscle walls of the right ventricle are much thinner than those of the left ventricle." — CONN AND BUDDINGTON.

blood from the heart, and *vein* is the term applied to the vessels which return blood to the heart. There is little structural difference between the veins and arteries except that the walls of the arteries are thicker, and there are no small valves as in the veins. As the branches of the arteries become minute, the walls become much thinner, thus allowing the food and oxygen to pass more easily to the individual cells. These minute branches are called *capillaries* (Latin, *capillus*, hair). From a cluster of capillaries a small vein begins which soon connects with a slightly larger vein, which leads back to the heart through larger and larger veins.

FIGURE 402.— DIAGRAM OF A VEIN SHOWING THE VALVES.

In which direction does the blood flow in this diagram?

The blood follows a regular course through the body, passing from the left ventricle into the *aorta*, which is the largest artery in the body. As soon as the aorta leaves the heart, smaller arteries branch from it, and the aorta itself also branches until the entire body is supplied with blood. The right ventricle gives off a short artery which divides, a branch entering each lung. At the point where an artery leaves a ventricle, there are three half-moon-shaped valves which prevent the blood from flowing back into the heart (Figure 402).

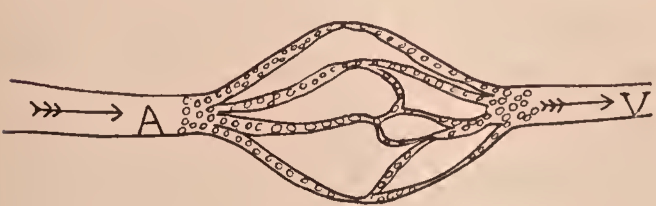

FIGURE 403. — DIAGRAM OF CAPILLARIES.

The artery breaks up into minute branches, the capillaries, which in turn unite to form veins.

The blood which is carried into the lungs contains a large amount of carbon dioxide which gives it a dark color. In the lungs the carbon dioxide is given off and oxygen taken up, so that when this blood is returned to the left auricle, it is of a bright red or "arterial" color.

Every time the heart beats the blood is forced into the

arteries in waves which can be felt in the wrist or neck by placing the finger over an artery. The wave is called the *pulse.* By counting the number of waves each minute, the rate at which the heart beats is determined. When a person runs or takes violent exercise, the pulse rate increases. It is advisable to know what our usual pulse rate is, for an increased pulse rate is sometimes an indication of approaching illness.

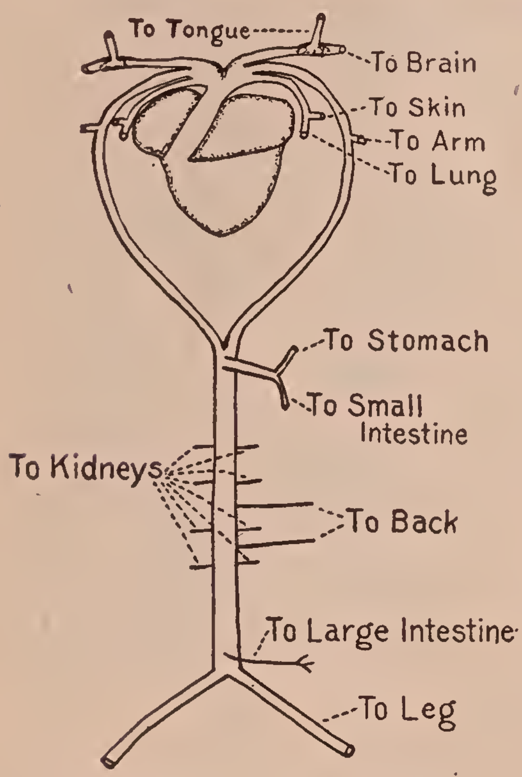

FIGURE 404. — MAIN ARTERIES OF FROG.

Closely associated with the pulse is the additional condition known as *blood pressure.* Blood pressure is the force with which the blood pushes against the walls of the arteries with every heart beat. Special appliances have been devised which accurately measure the amount of this pressure. The information thus revealed to the skillful physician is often very important.

Lymph. — As the blood flows through the capillaries, part of the plasma passes through the thin walls into the spaces between the cells and bathes the cells. This fluid which escapes from the capillaries is called *lymph* (lĭmf). It is composed of digested food, water, and other substances. The cells assimilate the food which they need and cast back into the lymph the wastes which they have formed in the process of growth and repair. These spaces between the cells are small and irregular in shape. The spaces, however, form a sort of mesh, or net, the parts of which join, forming larger vessels, and finally all the lymph is collected into two large vessels which open into veins. Thus there is the *lymphatic circulation* which differs from that of the blood in several

ways. (1) There is no special organ for forcing the lymph along, the circulation depending mainly upon the movement of the muscles. (2) The lymphatic vessels are imperfect in the beginning, being only irregular spaces. (3) The lymph contains no red corpuscles and only a few white corpuscles.

Cuts. — Since every part of the body inside the skin is traversed by blood vessels, we cannot injure any part without breaking some blood vessels. A small cut causes the blood to flow only from capillaries, and it flows slowly and in small quantities. If a vein be cut, the blood will be dark in color, and will flow in larger quantities, but steadily. A severed artery sends out bright red blood in waves corresponding to the beat of the heart. To stop the flow of blood from a vein, compress the vein beyond the cut; from an artery compress the artery between the cut and the heart. In either case remain quiet to aid the blood to form a clot.

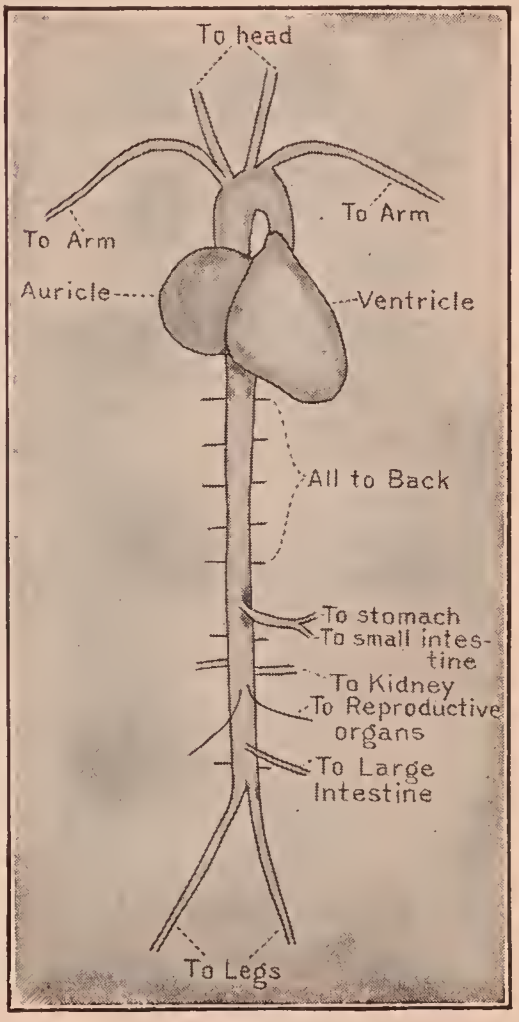

FIGURE 405. — MAIN ARTERIES OF MAN.

Compare with Figure 404.

Exercise. — The object of a circulatory system and of a circulatory fluid is to supply every cell in the body with food and to carry away the waste. The more active the process of circulation, the more perfectly is this object accomplished. It is the common experience that the heart beats more rapidly, the lungs work harder, and the body becomes warm after a few minutes of vigorous exercise. These changes have a decidedly beneficial effect upon building up the body and removing the wastes.

Fainting. — Fainting is due to an insufficient supply of blood in the brain. This lack of blood may arise from several causes, but the most common is some disturbance of the digestive processes, which causes the heart to beat too slowly. A fainting person should be placed flat on his back, if possible, with his head slightly lower than the rest of his body, and should be given plenty of fresh air. A dash of cold water in the face, or a bottle of ammonia held to the nostrils, is often helpful in restoring consciousness.

The Effect of Drugs and Alcohol. — "The flow of the blood is modified by various drugs, some causing the blood to flow more rapidly, others more slowly. Coffee causes

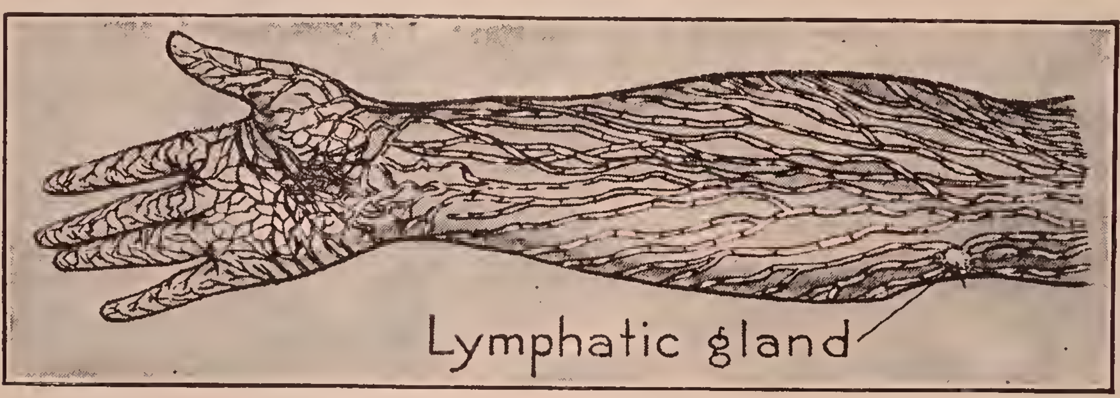

FIGURE 406. — SUPERFICIAL LYMPHATICS OF ARM AND HAND.

the heart to beat harder and at the same time causes some of the arteries to become smaller. For this reason it is called a stimulant." — CONN AND BUDDINGTON.

It has been stated frequently that alcohol increases the activity of the heart. Careful experiment, however, shows that not only is the effect not that of a stimulant, but that when used in large amounts, it markedly weakens the action of the heart. If taken only in small amounts, the heart sometimes shows a slight increase in its rate of beating, but this occurs only when the brain becomes excited, and if the person is kept quiet no change in the heart beat is noticeable. Thus the primary action is on the brain.

"A second effect of alcohol is more evident. The small blood vessels in the skin are enlarged. This produces a

flushed skin, a feeling of warmth, and a false feeling of increased circulation. Its result is to send more blood through the skin with consequent extra loss of heat. This action is evidently not due to stimulation, but to the relaxation of the muscles, and is thus a decrease of activity rather than an increase, even though the blood does flow a little more rapidly through the skin. These facts make it clear that alcohol cannot be properly called a stimulant of the circulatory system." — CONN AND BUDDINGTON.

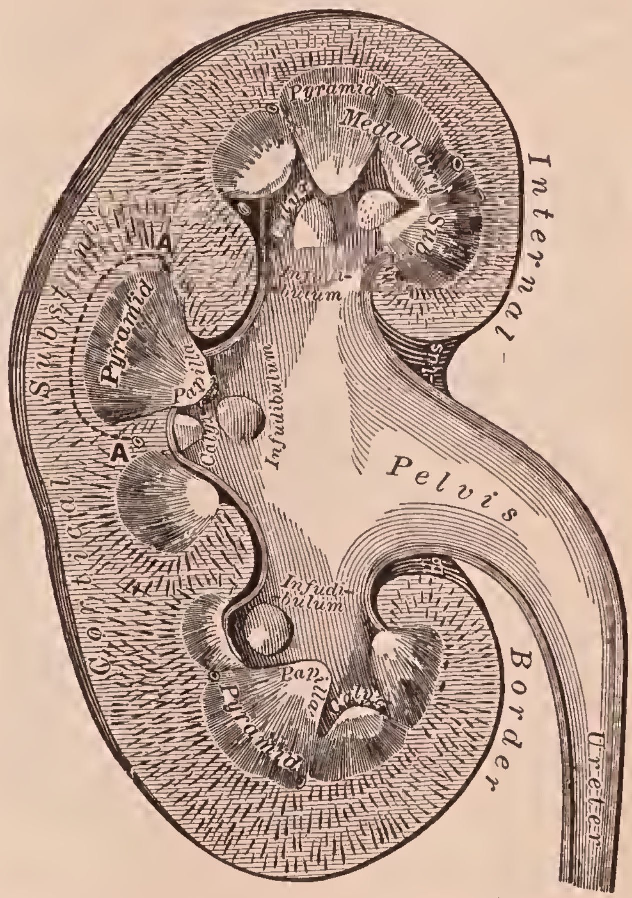

FIGURE 407. — LONGITUDINAL SECTION OF KIDNEY.

358. Excretion. — Every animal uses energy in carrying on its work. During this process a certain amount of waste substance is produced, which has to be removed from the body. The skin, kidneys, and lungs are the chief organs which assist the body in getting rid of this waste. When any part of the living cells is broken down in the simple act of living, a waste product results. By osmosis these waste products enter the blood and are removed by the lungs, which give off carbon dioxide, by the sweat glands in the skin, and by the kidneys, which remove the wastes that contain nitrogen. The sweat glands and kidneys are usually regarded as the excretory organs of man. These organs remove from the blood the wastes which have been excreted by the cells of the body. The excretion from the living cells is one of the fundamental life processes of all plants and animals. This form of excretion should not be

confused with the indigestible part of the food which is not taken up by the blood and which passes out through the large intestine as fæces.

The kidneys are two bean-shaped organs located in the abdominal cavity, one on each side of the " small " of the back. Each is about four inches long, two and a half inches wide, and half an inch thick. The color is a dark red. The kidney is made up of two layers, the outside or *cortical*, and the inside or *medullary*. Each layer is composed of many small tubes (*tubules*) which open into an area called the *pelvis*,[1] the space within the kidney. The pelvis continues into a duct (*ureter*), and from each kidney the ureter passes into the *bladder*. A small duct (*urethra*) (ū-rē′thrȧ) connects the bladder with the exterior of the body.

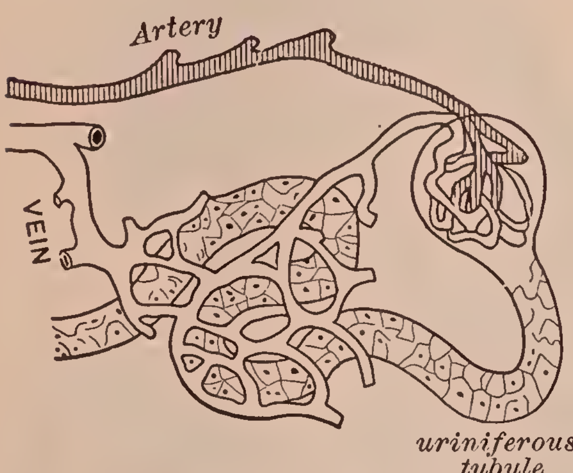

FIGURE 408. — DIAGRAM.

Showing relation of artery and vein to portion of minute kidney tube (uriniferous tubule).

Each tubule in the kidney is in close relation with the blood capillaries. At the place where this close relation is found, *glomerulus* (glŏ-mĕr′u-lus), the walls of the capillary and the walls of the kidney are very thin. Through these thin walls a large amount of water filters out of the blood into the tubes. At the same time waste material which contains nitrogen, salts, and other organic wastes is removed. If these wastes are not removed, they create toxins which poison the body.

Skin. — The skin covers and protects the voluntary muscles, regulates the body temperature, gives off waste matter, and acts as a general sense organ. Thus we see that it is incorrect to think of the skin simply as an organ of

[1] The word *pelvis* is also used in referring to the hip bones, and it is better to call the latter structure the bony pelvis.

excretion. In order to understand just how wastes are removed by the skin, it is necessary to study its parts. The outer layer of the skin is called the epidermis (Figure 409) and is chiefly composed of dead cells. These outer cells are constantly breaking off, a process which is most apparent in the case of sunburn. Whatever pigment or coloring matter there is in the skin is located in the inner cells of the epidermis. The amount and kinds of pigment determine whether a person is of light or dark complexion, white, black, or yellow. These inner cells are constantly growing new cells to replace the cells which scale off.

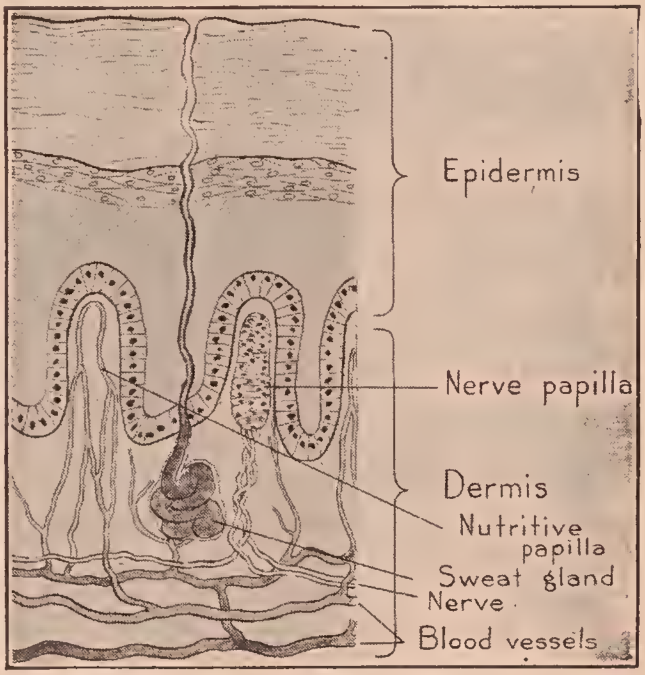

FIGURE 409. — DIAGRAM OF SKIN.

The nails and the hair arise in the outer layer of the skin. Other structures which arise in the same way are the scales of fishes and snakes, the hoofs and horns of cattle, and the feathers of birds.

The inner layer of the skin is the *dermis;* it contains blood vessels, nerves, connective tissue, the sweat glands, and sense organs of touch, pain, heat, and cold. It is estimated that there are over two million sweat glands in the skin of man. These are the excretory organs of the skin and their work is to eliminate waste substances from the blood and to keep the body temperature normal (98.4° F.) by regulating the amount of perspiration excreted. The amount of perspiration is influenced both by the temperature of the body and the air. The evaporation of perspiration keeps the body at the normal temperature.

The skin is attached to the body by a loose layer of con-

nective tissue in which fat is deposited. This is known as the subcutaneous layer of fat. This layer becomes very thick in corpulent people.

Leather. — The study of the skin which we have just made introduces us to some interesting biological problems connected with one of our commonest possessions — shoes. The skin of man is built upon the same plan as the skin of the animals from which the leather used in shoes, harnesses, grips, and gloves is manufactured. This large industry depends upon the structure of the skin, especially the arrangement of the fibers in the dermis. In the skin of a fish or an alligator, the fibers of the dermis run parallel and at right angles in the several layers, while in the hairy animals these same fibers do not follow any order of arrangement, which results in the production of a felt-work of interlacing fibers producing a strong skin which resists tearing or flaking.

Most of the leather that is used in shoes to-day is from the hides of cattle. Great numbers of these animals are slaughtered each year for food. Their hides must be removed with care so as to avoid cutting, as all such injuries destroy the fibers of the dermis. These hides are then sent to tanneries where each is made into a certain grade of leather, such as sole leather or the leather for the upper part of the shoe. This difference in thickness and firmness is produced largely by the method employed in tanning. When a vegetable tan is used, such as hemlock bark, oak, or sumac, sole leather results; and when a mineral tan is employed, leather suitable for the upper part of the shoe is secured.

Two common parasites, the white grub and the southern cattle tick, live in the skin and render it unfit for leather so that it is to the advantage of cattle breeders to keep their cattle free from these parasites. The United States Department of Agriculture has greatly assisted cattle raisers in exterminating these destructive parasites. The effort to exterminate the parasites, especially the southern

W. T. Sedgwick (1855–still living), head of the Department of Biology and Public Health at the Massachusetts Institute of Technology, has devoted his training and energy largely to making cities healthful. He is one of the foremost American biologists in making investigations upon milk, water, sewage, and epidemics of typhoid fever, and in showing how to apply these technical studies to human welfare.

He was one of the first to study the bacteria of the air, and his work on the "Principles of Sanitary Science and Public Health" (1902) was an important contribution to public health education. In addition to this marked service to his countrymen, he has devoted his life to teaching biology and sanitary science and to training biologists and public health workers.

One renders a great service to his age who leaves the world safer to live in than he found it.

cattle tick, was so successful that in 1918 hides valued at many millions of dollars were added to the general supply in the United States. Another biological factor in the production of good leather has reference to the care that the cattle receive. If they are well fed and properly housed during the winter and keep free from disease, then their hides have a better texture and are finer grained. The coarser grades of leather are made from older cattle and those that have little or no shelter in winter. Man has never been able to originate or create leather. It must be first grown as the skin of some animal. Man's skill consists in his manipulations of the hide after a living animal has grown it.

Sewage. — In every town and city where a general water supply is established, it is necessary to provide means for the removal of the waste water. This water comes from homes, places of business, and various manufactories. Not only the wastes from the human body but also from the street washing, the waste products of various factories, and the annual rainfall and snow are all added to the waste waters of a city or town. Such water is known as sewage. A great deal of study is being given to this problem that becomes more and more difficult as the number of people living in a given place increases.

It is now known that there is an average of one hundred gallons of sewage daily for every inhabitant of a city. The daily sewage from homes averages about thirty gallons for each member of a family; but when we add the street flushing and wastes of various manufactories the total amount per capita is not far from the larger amount named. Thus in a city of 100,000 inhabitants, there will be about ten million gallons of sewage a day. What must be the daily average of sewage in your city?

Disposal of Sewage. — The question of what shall be done with all this vast amount of sewage is one of the most difficult that cities are trying to solve. The cities that are

located on or near the ocean or Great Lakes let their sewage run into them. Those that are built on a stream or river empty into this small body of water and the town or city farther down the stream does the same. Smaller towns that are not located upon any body of water have installed filtration plants. These are very effective where the total amount of sewage is small. Where does the sewage of your city or town go?

Stream Purification. — Some recent studies made under the direction of the Massachusetts Institute of Technology show that there are a number of biological factors that assist in the purification of sewage polluted water. These are a number of organisms that feed upon the organic matter that is suspended in the water. The first living things to be found where the water is most polluted are bacteria. As the sewage empties into the stream it is rich in food for bacteria and they become very numerous. As they feed upon this food, it is broken up into simpler chemical bodies and the water becomes clearer. A little farther away from the mouth of the sewer, are found numerous protozoa that feed upon these bacteria and thus tend to remove them from the water; while still farther down the stream, are to be found numerous tube-bearing worms that in turn feed upon the protozoa. If the water is now examined, it is found to be much clearer for most of the sediment has either settled to the bottom or been destroyed by these several organisms. Such water as this is not fit to drink.

Water Supply. — Plenty of pure water for drinking and cooking is indispensable to man. The necessity for disposing of the sewage has made this problem increasingly difficult. Sewage-polluted water is never entirely safe for drinking water. The two must be kept separate. This is the main reason why so much money has had to be spent to bring our drinking water to the cities and this is the reason why so much care is taken to prevent this same drinking water from

becoming contaminated. Some of the smaller towns have not yet come to appreciate the value and importance of having pure water to drink. The result is frequent epidemics of sickness.

In Figure 410 is shown a model reservoir for a small town. The reservoir is located on a high piece of ground and all possible sources of surface drainage have been eliminated. The surroundings are graded so that standing water cannot

FIGURE 410. — A MODEL RESERVOIR.

accumulate and become impure to flow later into the reservoir. In Figure 411 is shown a reservoir in which the conditions are the reverse. The water is stored in a place surrounded by residences and swampy ground on the left of the photograph. The open channels in the grass are streams that empty into the water of the reservoir. One of these is supplied from the overflow of water of the Erie Canal. This alone is sufficient explanation of why there have been frequent epidemics in the town that has this water supply. What are the conditions surrounding the water supply of your home?

In the country, the water is taken from wells and springs, which are splendid sources of water when properly protected

from the drainage of the house and barn. But people in the country are not as alert as those in the city and do not give as much attention to this important aspect of preserving their health as they should. In fact a great many people in the city would give no attention to it, were they not compelled to do so by the health laws of their state. Because uniform laws are being enforced in our cities and larger towns, these places are more healthful to live in than the country

FIGURE 411. — A POOR RESERVOIR.

Note the open stream that empties into the main body of water. The impure water of the Erie Canal drains into this open stream.

where each one is a law unto himself so far as protecting his water supply is concerned. Many people do not understand how water can be impure when it looks clear and there is no sediment. Nor do they comprehend that the air likewise can be impure although it looks clear. We shall soon learn that through the studies of technical scientists, there have been discovered organisms, which cause sickness, that are so small as scarcely to be visible with a microscope. These minute organisms live in the air and water and one cannot tell anything about the purity of the air or water by looking at it.

SUMMARY

All living things breathe oxygen which, in man and the higher animals, is carried by the blood to the cells of the body. The parts which man uses in breathing are more highly developed than in any other animal. Man has a voice box, the larynx, by means of which he is able to make a wide variety of sounds. The blood of man is similar to the blood of all other vertebrates, although not identical. It consists of red and white corpuscles which move freely in the plasma. The blood is confined in the blood vessels through which it is forced by the heart. Excretion includes the waste products derived from the living protoplasm. The lungs, the sweat glands of the skin, and the kidneys remove this waste from the blood. The care of waste requires that we give increasing attention to the question of sewage and water supply.

QUESTIONS

Compare the respiration of man, the hydra, and the earthworm. Compare the lungs of man with the gills of a fish. What is blood? What are its uses? What is the difference between veins and arteries? Explain the work of the skin and kidneys. What is sewage? How is it cared for in your home? city? town? Where do you get your water supply?

CHAPTER XXXIV

THE NERVOUS SYSTEM OF MAN

359. Parts of the Nervous System. — The nervous system of man consists of the same general parts as the nervous system of the frog (see page 88). There is a brain and spinal cord, from which nerves extend to the special senses, the muscles, the heart, and the stomach. When the brain of man is compared with that of the frog, it is obvious that the cerebrum of man is proportionately larger. Although some of the other parts of the brain appear unlike the corresponding regions in the frog, scientists tell us that they are really the same.

360. The Nerve Cell. — The nervous system of man consists of many thousands of nerve cells which differ from all other cells in having more parts and branches (Figures 413, 414, 415). Examination shows that the nerve cells have a prominent nucleus surrounded by cytoplasm, which grows out into a number of branches called fibers. The shorter branches divide and form, together with the branches from the neighboring nerve cells, a mass of tangled fibers. There is usually one unbranched fiber, perhaps several feet long, which ends either in the skin, in some muscle, or in the spinal cord or brain. When this long fiber reaches the muscle or skin, it divides into several fine branches. All these branches which arise from a nerve cell belong to it, and in this connection the word cell includes all the branches, the nucleus, and the cytoplasm.

361. The Location of the Nerves. — The nerve fibers which have the same work to do occupy certain definite

places in the brain and spinal cord. A student of the nerves can tell the route which the stimulus arising from feeling a pencil must travel before reaching that part of the brain where it is interpreted as a pencil; or the route over which the stimulus arising from tasting candy must pass before it is known to be that of candy. When we see the pencil or the candy, the route over which the sight stimuli of these two objects travel is not the same as that of the feeling of the pencil or tasting the candy. The nerve cells which interpret the stimulus arising from feeling the pencil or from tasting the candy or seeing the pencil and the candy are probably not the same. We may say, therefore, that the spinal cord and brain are made up of many special nerve pathways which end in nerve cells that interpret stimuli.

FIGURE 412. — NERVOUS SYSTEM OF MAN.

The nerves which connect the central nervous system, that is, brain and spinal cord, with all parts of the body, consist of many long nerve

fibers. Each nerve looks like a small white thread and is covered with a thick, fatty sheath (medullary sheath). In the living animal, this fatty sheath is white and the nerve fibers so covered are found to occupy a certain part of the spinal cord and brain. Thus, we get the name *white substance.* Other of the nerve fibers and cell bodies are not covered with a sheath and so have a gray appearance. Thus we have the term *gray substance* in connection with the nervous system.

The Central Nervous System. — In Figure 412 the nerves of the legs, arms, and trunk are all seen to be united to a central body, the spinal cord. There are nerves in the upper part of the neck and in the head region that unite with the large mass at the upper end of the spinal cord, the brain. The brain and spinal cord are known as the central nervous system. The brain is divided into the following parts: cerebrum, the most anterior; the mid-brain, to which the optic nerves join; the cerebellum; and the medulla oblongata, to which the nerves of hearing, tasting, and the facial nerves belong.

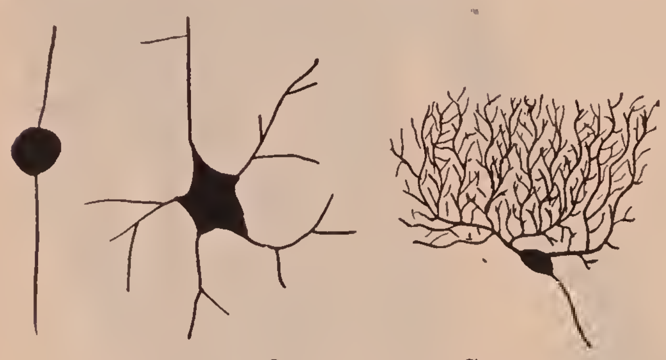

FIGURE 413. — NERVE CELLS.

Stained by the silver process which blackens all the parts. This is an excellent stain to show the branching processes.

The cerebrum is the most important of the several regions of the brain. It regulates and controls all our nervous activities. The cerebellum gives tone and vigor to the contraction of the muscles and helps us to know when we are properly balanced and is hence known as the equilibration center. The remaining parts of the brain give off and receive nerves and transmit nerve stimuli to the cerebrum and cerebellum.

362. Growth of the Nervous System. — The nervous system of man, like all other parts of the body, has a definite

beginning and grows in an ordered manner. Not only is this true in man, but also in the frog and fish. The tissue of the embryo, which is to grow into brain and spinal cord, gradually changes until the adult parts are formed. During this early period of growth, the nerve cells send out processes which become nerve fibers, so that at birth the nervous system is ready to go to work. Indeed, nearly all the nerve cells which the human being is ever to use are made before birth. These cells gradually become more active and the different parts of the brain work more perfectly as we go through the periods of childhood, youth, and maturity. The brain becomes a more perfect working organ by making the brain cells do their specific work over and over and over, until each group of cells can be relied upon to do a definite thing.

FIGURE 414.— NERVE CELLS.

Stained to bring out the minute parts in addition to the nucleus.

363. Reflex Action. — Reflex action is the simplest form of nervous activity in man. For example, when the finger is placed on a hot stove and suddenly withdrawn the following actions take place. The heat stimulus affects the nerve endings in the finger and that stimulus is carried to the spinal cord. If this were all that occurred, the finger would burn, because this stimulus and the nerve fibers over which it travels have no control over the muscles. The removal of the finger is brought about by another set of nerve cells — the cells which have their fibers ending in the muscle of the hand and arm. All these changes take place involuntarily, and the reaction to the stimulus is known as reflex action. Specific names are used in describing these several changes;

the nerve fibers which connect the skin with the spinal cord and brain are called *afferent* (ăf′fĕr-ĕnt: Latin, *ad,* to; *fero,* to carry) fibers because the stimulus always travels towards the brain.

Their function is sensory, for they carry the stimulus to the brain. The fibers which connect the muscle with the brain or spinal cord are the *efferent* (ĕf′fĕr-ĕnt: Latin, *ex,* from; *fero,* to carry) fibers, because they carry their message away from the central nervous system. Their function is to produce motion. In the special instance we

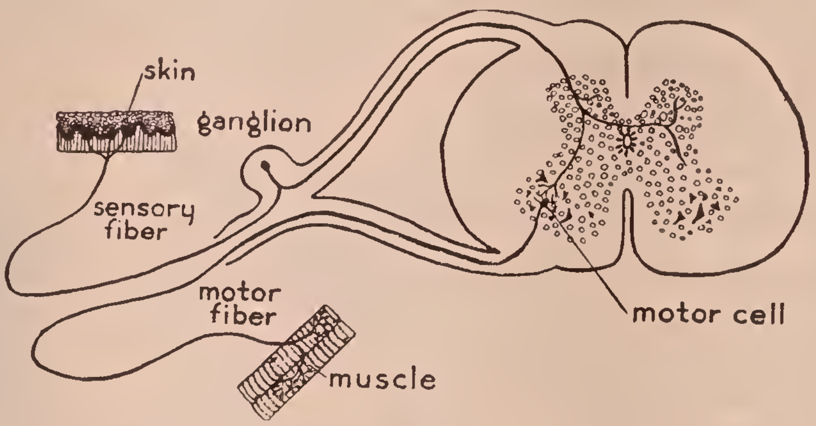

FIGURE 415. — DIAGRAM TO SHOW REFLEX ACTION.

The stimulus comes in contact with the skin and is carried to the spinal cord. It then passes to the motor cells which carry the order to the muscle. The same skin stimulus goes to several other parts of the spinal cord.

are studying, the heat stimulus causes the spinal cord to send a special message to the muscles of the finger, so that the latter is removed from the stove.

This is a typical illustration of the simplest way in which the nervous system works, but in most reflex actions there are other results. After the finger has been removed from the hot stove by reflex action, we soon realize that the skin is burned, the realization coming through the smarting sensation. This second stimulus has been carried to the brain, and we are now conscious of the stove, heat, burn, etc. If there were no afferent nerve fibers, the individual could not experience any pain when hurt.

The afferent and efferent nerves, whether in reflex or in general nervous action, never vary in the work which they do. The sensory afferent nerves form the only paths over which our information of the outside world travels to the brain. The stimuli which cause the different sensations, such as taste, sight, etc., have their individual paths and receiving organs. This is indicated by the fact that no other nerves than those of the ear are ever affected when we hear.

Reflex Action in the Frog. — The frog, like man, is able to act in a definite way. If any one approaches a frog while it is sitting on the edge of a pond, it jumps into the water, stirs up the mud, and then returns to the shallow water near the place where it entered. The frog, in this case, acts as if it, or its ancestors, had learned that this is the best way to escape enemies. While this series of acts is called a habit, it is really a series of reflex acts which are similar to the reflex action described for man, and require the same nerve structures.

Reflex Action in the Earthworm. — If a light is flashed on an earthworm at night, the worm will quickly withdraw to its burrow, before it can be seized. The earthworm has no eyes, but it is able to respond to light and can tell the difference between night and day. It is believed that special nerve cells in the skin, which are connected with the nerve ganglia, help the earthworm to become aware of the light stimulus.

Reflex Action in Hydra. — Hydra is a minute water animal which has no definite nervous system, but only a few nerve cells scattered through the body. As the hydra waves its arms about in the water, there seems to be no purpose in its motions. But if a water flea swims against one of the tentacles, a part or all of the tentacles at once begin to carry the flea to the mouth of the hydra. The hydra, then, without a definite nervous system, can carry out a definite reflex action.

Reflex action is similar in all animals. In all these illustrations, it is necessary for the stimulus to be received by an afferent nerve, or some structure which can do the same work, and for the stimulus to be transformed into a series of purposeful movements.

364. Sense Organs. — All the higher animals have eyes, ears, a nose, and a tongue. Each of these organs contains nerves specialized to respond to a certain definite kind of stimulus. The result of this specialization is that not only are these special sense organs complex in structure, but also the region of the brain which receives their messages. The ear nerve responds to a stimulus of air-waves of a certain length, and we say we hear a sound. The eye nerve is stimulated only by light. Each nerve and the brain cells to which it sends its messages have become so specialized that practically only one kind of reaction takes place. For example, all stimuli acting upon the eye nerves are interpreted as light.

The skin is a simpler sense organ than the eye or ear, and tells us of pain and touch and the difference between heat and cold.

Smell and Taste. — These two senses are closely related. The sense of smell is located in the nose and the organs of smell are minute nerve cells scattered among the regular cells that line the nasal passageway. The olfactory nerve which carries smell stimuli to the brain is the shortest nerve in man.

Taste has already been described in connection with the digestive system on page 405.

The Eyes. — The eyes of all vertebrates have the parts arranged in a similar manner. The eyeball is roundish and is located in the eye sockets of the skull, which are termed *orbits*. There is an upper and a lower eyelid, and the remains of a third eyelid in the corner next to the nose. The front of the eye is covered by a transparent mem-

brane, the *cornea* (kôr′nē-a); and the rest of the eye is surrounded by a tough membrane, the sclerotic coat, or the white of the eye. Within the combined covering of the cornea and sclera are a number of structures which take part in receiving and transmitting the rays of light to the brain.

A cross section of the eye shows two more membranes in close relation to the sclerotic coat (Figure 416). The membrane in direct contact on the inside with the sclerotic layer is the *choroid* (kō′roid). The choroid coat is filled with blood vessels and pigment. Through this layer the food in the blood is distributed to the eye. The third layer or coat is the retina, which is composed of nerve cells and is nearly transparent.

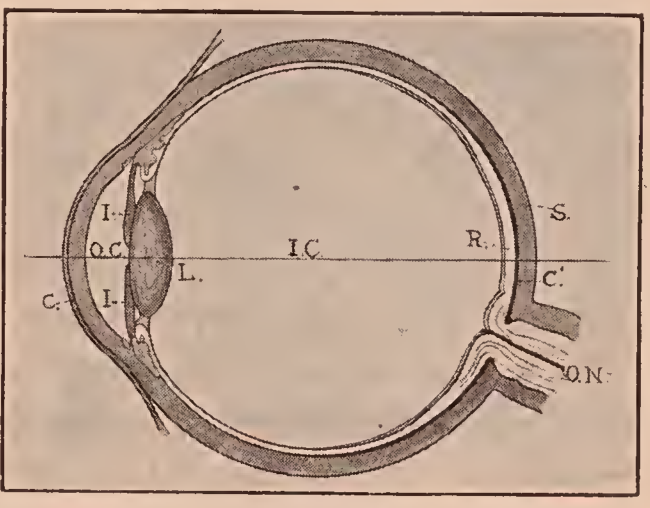

FIGURE 416. — SECTION OF EYE.

C, cornea; *C′*, choroid layer; *I*, iris; *I. C*, inner chamber; *O. C*, outer chamber; *L*, lens; *O. N*, optic nerve; *R*, retina; *S*, sclerotic coat.

The cornea and these three layers inclose two chambers which are separated by the *lens* (Figure 416). In front of the lens a curtain-like membrane, the *iris*, partly covers the lens, except for a round opening in the center which is called the *pupil*. The color of the eye, gray, black, blue, or brown, is due to the presence of pigment in the iris. The small front chamber is filled with a transparent fluid which is composed principally of water and is known as the *aqueous* (ā′kwē-ŭs) humor. The large back chamber is filled with a thin, transparent, jellylike fluid, the *vitreous* (vĭt′rē-ŭs) humor.

In order that we may see any object, a pencil in our hand, for example, two general conditions must be present. The picture (image) of the pencil must be placed on the

retina, and this picture must be carried to the brain by the eye (optic) nerve. When these two conditions take place, we see.

As we have learned, the stimulus for the eye is always light. In physics we learn that the rays of light travel in straight lines. This fact explains why we cannot see round a corner. When the rays of light are made to pass through a glass lens, the rays which pass through the thin edges of the lens are bent and do not travel to the same place they would have reached had they not passed through the lens. In the same way light rays from an object pass through the lens in our eyes and are bent. This results in the image of the object, the pencil in this instance, being inverted on the retina. The light rays of the pencil stimulate the nerve cells in the retina, and this stimulus, after being carried to the brain, is interpreted to us as a pencil, though we do not know how stimuli travel on nerves.

FIGURE 417.—HOW WE SEE THE PENCIL.

The inverted image of the picture on the retina is due to the shape of the lens. When the stimulus reaches the living cells of the retina and through them is passed on to the optic nerve and the brain, a series of changes takes place in these living cells. There is no evidence as to how an inverted or upright picture passes through these living cells in the retina and brain. We do know that we have to learn the meaning of all stimuli. For example, a baby reaches for things far beyond the length of its arms and it is only after many trials that it eventually acquires precision in reaching for an object. It is probable that each one of us passed through a similar stage of learning to interpret the stimuli that arose from light. In coming to understand light stimuli, the sense of touch was of great assistance. Try to explain how this would be so.

Care of the Eyes. — The eyes are our most precious sense organs, and as such they should receive the best of care. Certain imperfections in the lens or other parts of the eye can be helped by the use of glasses. If your eyes annoy you, or if you cannot see objects as clearly as your schoolmates, have a competent oculist examine and treat them.

The Ear. — The ear is a sense organ for the reception of the stimuli which we interpret as sounds. The ear of man consists of the outer, middle, and inner ear. The first two carry the stimuli to the third, where they are received by nerve cells and carried to the brain.

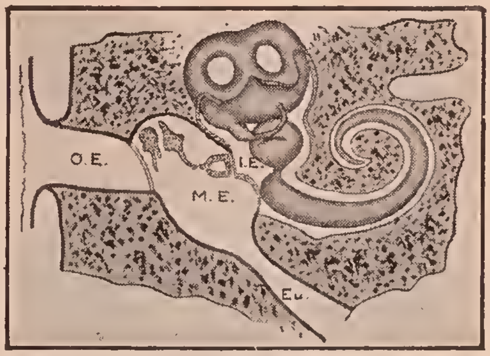

FIGURE 418. — PLAN OF EAR.

O. E, outer ear; *M. E*, middle ear; *I. E*, inner ear; *Eu*, eustachian tube.

The diagram of the ear (Figure 418) shows the several parts and their relations. The outer ear leads to the *tympanic* (tĭm-păn′ĭk) cavity; the middle ear is in communication with the mouth, and the complex inner ear is partly shown. There is a group of small bones in the middle ear which conduct the sound vibrations to the delicate inner ear. The internal ear receives the various sound waves, and transmits them to the brain, where they are explained as sounds.[1]

Hearing. — Sound waves strike the ear drum (tympanic membrane), which in turn causes the small bones in the middle ear to vibrate. The bones cause the water in the internal ear to move, thus stimulating the nerves of hearing.

The pressure of air on each side of the ear drum is normally the same. This is due to the entrance into the middle ear of air from the mouth, through the eustachian tube

[1] When certain parts of the ear (semicircular canals) are injured, one has difficulty in standing or in walking erect. This is because the inner ear serves both as a hearing and a balancing organ.

(see page 406). This tube is a trifle more than an inch long. When it becomes closed, partial deafness results.

Defects in hearing may be caused by blows upon the ears, by the accumulation of wax in the ears, and by sore throat. When there is a continued ringing or hissing sound in the ears, consult a doctor at once.

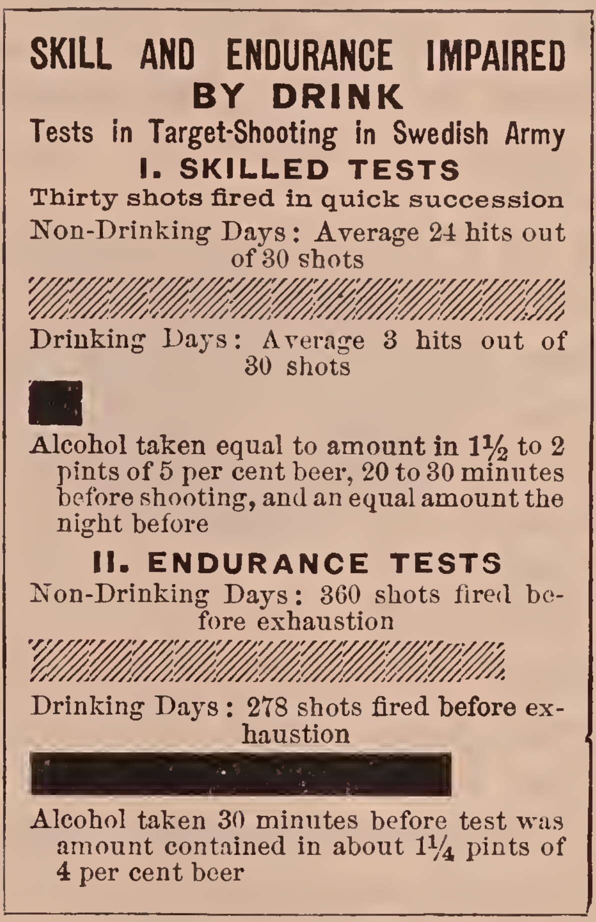

Figure 419.

365. Brain Efficiency. — While the efficiency of the brain depends upon mental training, in order properly to exercise the many functions of this organ at least three things are necessary: good food, sufficient sleep, and abstinence from alcohol and tobacco. We have already discussed the question of food (page 410).

The amount of sleep which grown people need depends in part upon the kind and amount of work they do. But all young people require a large amount of sleep. Children from seven to ten years of age need at least twelve hours of sleep every night, while youths of high school age need at least nine hours, and ten would be better.

At a baseball game, you have noticed a boy catch a "fly" when it looked like a "home run," or how enthusiastic the crowd became when the pitcher struck out the last man with the bases full. The nervous system of both players was efficient in a critical test.

We all ride on the street cars or railroads, but do you know that most of the men who run the street cars and

trains have to pass an examination to determine whether they can be trusted to do their work properly and well; *i.e.*, whether their nervous systems will stand the test? Among the questions which their prospective employers are sure to ask is, "Do you use alcoholic drinks?"

In order to judge the success of a piece of work we must consider the quality and speed with which it is done. Kraepelin made the following experiment, the results of which show that both these elements in mental work are influenced by the use of alcohol.

Several men who were allowed to drink no alcohol utilized half an hour daily for six days in adding figures. Their ability to add increased each day. On the seventh day the work was begun under the influence of alcohol. In spite of the skill gained in the previous practice, their accuracy did not increase, but on the contrary began to decrease rapidly. On the nineteenth day the use of alcohol was stopped, and immediately an improvement in the work manifested itself; but on the twenty-sixth day, when the use of alcohol was resumed, a decided decrease in the power of adding manifested itself.

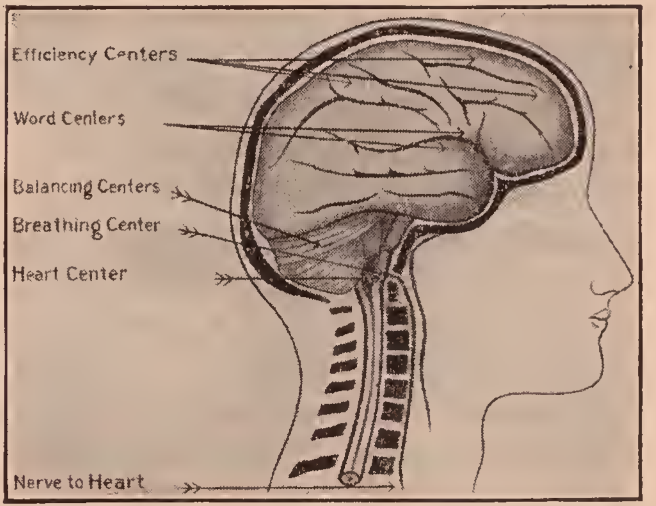

FIGURE 420. — BRAIN CONTROL.

It is difficult to estimate how efficient each of us may become in our life work, but one thing is certain, that if we use alcohol, we shall lose that perfect control over our nervous systems, which enabled the two players to be so efficient in the ball game. It is also equally certain that if we use alcohol, we shall find fewer men willing to employ us in places of responsibility, not only because of our

mental inefficiency, but also because of our unreliable judgment.

Alcohol Shortens Life. — In 1909 forty-three of the leading insurance companies in the United States and Canada agreed to make an impartial study of all their records for the past twenty-five years. This involved an examination of 2,000,000 insured lives. The insured were divided into many classes, such as railroading, mining, manufacturing, and users of alcoholic liquors. The two following statements are made by Arthur Hunter, the chairman of the committee, in a study covering a period of three and one half years.

"*Liquor Business.* — There is a general impression that saloon keepers do not live as long as persons in non-hazardous occupations, but it is not generally known that most classes which are connected with either the manufacture or sale of liquor have a high mortality. Among saloon proprietors, whether they attended the bar or not, there was an extra mortality of 70 per cent; and the causes of death indicated that a free use of alcoholic beverages had caused many of the deaths. The hotel proprietors who attended the bar either occasionally or regularly had as high a mortality as the saloon keepers, *i.e.*, the lifetime was reduced about six years on the average on account of their occupation. The mortality among those connected with breweries was about one third above the normal. The large class of proprietors of wholesale liquor houses had an extra mortality of about one fifth. In the fourteen subdivisions of the trades connected with the manufacture or sale of alcohol, there was only one class which had a normal mortality, and that was the distillery proprietors. The facts regarding the adverse effect on longevity of engaging in the liquor trade are such that, if they were generally known, young men who are easily tempted would be deterred from entering this business.

Habits as to Alcoholic Beverages. — Nothing has been more conclusively proved than that a steady, free use of alcoholic beverages, or occasional excesses, are detrimental to the individual. In my judgment, it has also been proved beyond peradventure of doubt that total abstinence from alcohol is of value to humanity; it is certain that abstainers live longer than persons who use alcoholic beverages. The low mortality among abstainers may not be due solely to abstinence from alcohol, but to abstinence from tobacco, and to a careful regard for one's physical well-being.

Among the men who admitted that they had taken alcohol occasionally to excess in the past, but whose habits were considered satisfactory when they were insured, there were 289 deaths, while there would have been only 190 deaths had this group been made up of insured lives in general. The extra mortality was, therefore, over 50 per cent, which was equivalent to a reduction of over four years in the average life of these men. If this meant that four years would be cut off the end of the average normal lifetime of each man, there are many who would consider that 'the game was worth the candle'; but it means that in each year a number of men will die at an earlier age than they should. For example, at age 35, the expectation of life is 32 years: in the first year after that age, instead of, say, 9 persons dying, there would probably be 12 deaths; that is, three men would each lose 32 years of life; in the next year probably four men would each lose 31 years of life, etc. As a matter of fact, many immoderate drinkers would live longer than 32 years, but not nearly so many as would live if they had been moderate drinkers, and far fewer than if they had been total abstainers from alcohol."

366. Alcohol, a Narcotic. — Before studying this subject further we must understand the meaning of the terms *poison*, *anesthetic* (ăn-ĕs-thĕt′ĭk), and *narcotic*. A poison is a substance which when taken into the body tends to cause death. Aconite, opium, carbolic acid, and mercury are all poisons, and when taken in sufficient quantities cause death.

An anesthetic is a substance like ether or chloroform, which when breathed into the lungs causes a temporary loss of sensation. Unless anesthetics are administered properly, they may cause death.

A narcotic is a substance which causes dullness or stupor, and even a temporary relief from pain.

To understand how alcohol comes to be classed as a narcotic, it is necessary to learn about a substance called *lipoid* (lĭp′oid: Greek, *lipos*, fat; *eikos*, like); and as you read about this substance in protoplasm, you will realize that the charges against alcohol have a real scientific basis.

"Within recent years a new sort of body substance has been discovered, and has been elevated to first-rate importance. This new

class is termed 'lipoid.' Its importance is immense. It is quite as important in the body as the nitrogenous or albuminous material which is present in every living tissue. It is very like fat in many respects, but in other respects it is different. It contains nitrogen, which fats do not; it contains phosphorus, which fats do not; again it mixes with water, which, as is well known, fats do not. It has certain remarkable properties, in that it can make certain bodies soluble which are otherwise not soluble.

"The walls of practically every living cell in the whole body are made chiefly of lipoid, and it is found that there are strands of this material running through and through the substance of every cell. In fact, there is no region of any cell in any part of the body that is without this material.

"Perhaps the largest accumulation of lipoid is that in the nervous system. There is far more lipoid in the brain than in any other tissue. If you examine a nerve, or what physiologists call a nerve trunk, you will find that this nerve is composed of many thousands of nerve fibers, and each nerve fiber that conveys messages into or out of the brain is invested with an insulation jacket (similar to the insulation covering an electric wire) of lipoid and thus the stimuli are prevented from scattering.

"It may be asked, 'What has all this to do with alcohol?' The connection is an important one, for only a few years ago two physiological investigators, — one with the English name of Overton, and the other with the distinctly German name of Hans Meyer, — without knowledge of each other's work, discovered the principle that any substance that dissolved lipoid, or, what is the same thing, is dissolved in lipoid, is an anesthetic. Chloroform, ether, and all of these agents which are used in modern surgery to produce unconsciousness are dissolvers of lipoid.

"Besides acting as anesthetics such substances act as poisons to every living thing in the body as well. The brain, owing to its high percentage of lipoid, is more sensitive to the action of chloroform than other organs of the body.

"When chemists and physiologists found that lipoid was soluble in alcohol, it enabled them to rank alcohol as a narcotic poison, and it is now so classed. This statement is altogether irrespective of the effects it will produce on an animal." OSBORNE.

The question of brain efficiency is further illustrated by Figure 420. Long before birth the heart in the embryo begins to beat and is under the control of the nervous system.

The part of the brain which superintends the heart is located in the medulla, where a special cluster of cells sends out nerve fibers which enter the heart nerve. These nerve cells are called the heart center.

The next nerve center to begin work is the breathing center, located close to the heart center, which controls the breathing. This does not become active until after birth.

About a year after birth, several more nerve centers become active in the child's brain. These are the ones which help him to walk. The cerebellum contains nerve centers which play an important part in walking and in learning to balance. The muscles which move the arms and legs are regulated by nerve centers in the cerebrum.

Soon after the child learns to walk, he begins to talk and learn words. The several nerve centers which now become active are all located in the cerebrum. These are the nerve cells which are necessary in speaking, hearing, reading, and writing words.

After the age of fifteen years the brain goes through important structural changes and the young person begins to do hard tasks well. It is difficult to locate the exact spots in the cerebrum where the nerve centers are that now become active, for they are widely distributed. These nerve centers may be called the efficiency centers and they are the last to develop. But as they become active, every one becomes skillful in respect to some one thing, although many years of training are necessary before the maximum of efficiency is reached.

The efficiency centers which are the last to become active and which require so much energy to train properly are the first to be affected by alcohol.

367. Structural Changes Due to Alcohol. — Definite changes are found in the protoplasm of nerve cells after the use of alcohol. These consist in a shrinking of the nucleus, the loss of the spindle-shaped (*Nissl*) bodies (Figure 414), the swelling of the cell, and the presence of vacuoles in the

cytoplasm. It is also probable that some of the nerve cells are actually destroyed. These physical changes explain why the results are so great and why complete recovery of mental efficiency in the drunkard is so doubtful. The modern point of view and the one which is becoming firmly established in the treatment of drunkards by physicians is that alcoholism is a disease.

Anything which can destroy all the higher and finer emotions, take away ambition, destroy shame, modesty, pride in personal appearance, render one especially liable to common diseases, or lead unerringly to insanity is to be avoided by all.

368. Tobacco. — "Training starts to-morrow, no more smoking," is part of the athletic coach's orders at the beginning of each season. He knows that the boy who smokes cannot reach his highest efficiency or be relied upon at critical times in the contest. He would rather have boys who do not smoke, because they are stronger, larger, and steadier than those who smoke. The cigarette habit has spread until it threatens the health of thousands of boys of America to-day. How is it known that their health is not good? The charts on "smoker's heart" prove this point.

369. How the Smoker's Heart Is Affected. — The following illustrations on the rate of the heart beat and the strength of the pulse, by W. A. McKeever, for thirteen years professor of philosophy in Kansas University, show what really happens when we smoke. There is much in these illustrations to warrant the conclusion that the heart of the habitual cigarette smoker is weak and feeble, except for the few minutes during which he is indulging the habit, and that the pulsations at this time are unduly excited. Figure 421 shows three records of a young man nineteen years old who began smoking cigarettes at the age of fifteen and who inhaled the fumes. The three records were taken without removing or readjusting

the instrument, as follows: No. I, immediately before smoking; No. II, during the indulgence of the habit, and No. III, fifteen minutes later, after the effect of the narcotic had become apparent. Now, by reference to Figure 422, No. III, we may observe how this young man's heart should record itself, for the latter is the tracing of the heart pulsations of a normal young man of the same age and temperament. Nos. IV to VI (Figure 421) are representative of another inhaler twenty years old, who began the practice at thirteen. He now uses a strong pipe.

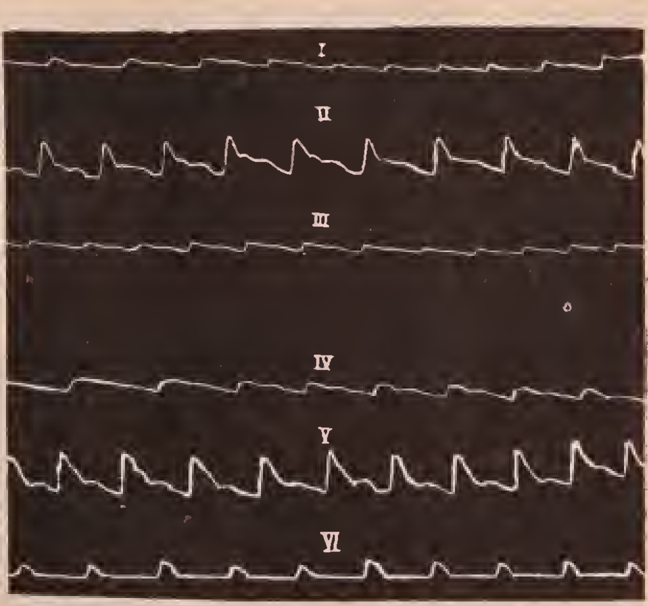

FIGURE 421.

In Figure 422, Nos. I and II, taken respectively before and after smoking, are tracings of a sensitive youth of eighteen who has been smoking only two years. Observe the skip of his heart beat at x and the corresponding partial skip under the stimulus of smoking in No. II. No. III (Figure 422), as mentioned above, is a tracing of a strong healthy heart of a young man of somewhat excitable temperament. No. IV represents the phlegmatic temperament, that is, a person who is not excitable. No. V is the heart tracing of a strong and healthy young woman.

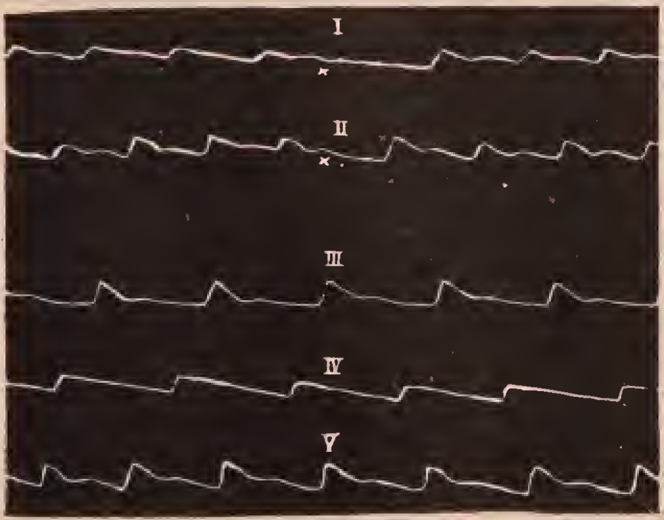

FIGURE 422.

In Figure 423, Nos. I and II are the pulse records of a man of splendid physique, thirty-six years old and weighing 230 pounds. No. I was taken before and No. II after smoking a cigar. He does not inhale. His pulse responded readily to the stimulus, but as the first tracing indicates he does not seem to suffer from any heart prostrations between indulgences. No. III is the record of a person whose vitality is temporarily low from nervous fatigue. No. IV is the record of a young woman who was on the verge of nervous prostration. No. V is representative of a heart weakened by long indulgence in the smoking habit. The young man in question began early and continued the practice till his physician convinced him of the extreme danger threatening his life. The pulse wave is nearly normal in length, but is entirely too weak. Under such conditions of heart action a man is capable of little courage or aggressiveness.

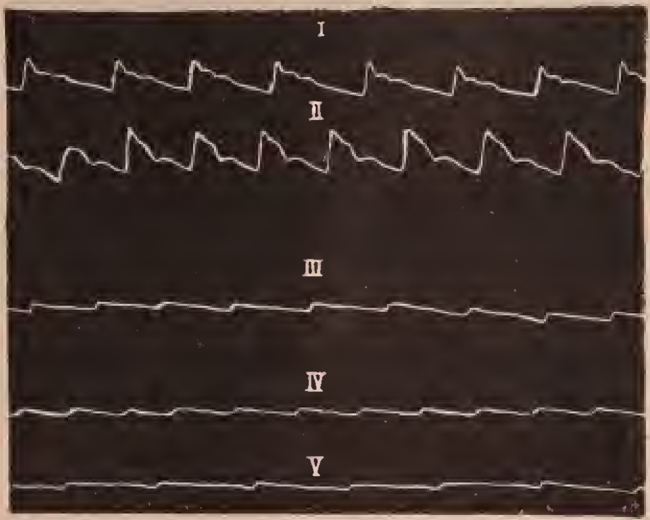

FIGURE 423.

Says Mr. McKeever:

"From the foregoing evidence we are led to the conclusion, that in the case of boys and youths, cigarette smoking is very deleterious to the physical and mental well-being. Moreover, my investigations indicate that it makes very little difference in the effects whether the victim uses pipe or cigarettes, provided he inhales the fumes; and with few exceptions the young smokers are inhalers. The ordinary case exhibits about the following type of conduct: (1) While the craving is at its height the victim manifests much uneasiness and often much excitation. (2) During the indulgence the cheek is alternately flushed and blanched, the respiration considerably increased, and the hands tremble. (3) About twenty minutes after smoking the muscles become relaxed, the respiration slow and shallow, the skin on the face dry and sallow, and there is an apparent feeling of unconcern about everything."

370. Smoking and Scholarship. — Several thousand boys have been studied and classified according to age and whether they were smokers or non-smokers. In all cases the non-smokers had a higher average grade of scholarship. The experience of city superintendents and principals is that they can usually tell a cigarette boy by his general attitude, poor scholarship, and disregard of personal appearance.

When cigarettes are burned, three distinct poisons are produced, which cause serious effects on the boys who use tobacco in this form. These poisons are absorbed in small quantities by the mucous membrane which lines the nasal passages and in larger quantities when the smoke is inhaled in the lungs.

A simple way to prove that cigarette smoke contains a poison is by blowing the smoke through a glass tube into an aquarium containing goldfish. Only a small amount of smoke will kill the fish.

While we all can gradually adapt ourselves to small amounts of poison, poisons are never beneficial unless prescribed by a physician to try to remedy some bodily defect. The poisons which arise from the burning of a cigarette are never prescribed even as medicines, and have never been found in any way beneficial to the human body.

SUMMARY

The nervous system of all vertebrates consists of a brain and spinal cord with nerves passing to all organs of the body. The brain of man is the most highly developed.

All our movements are controlled by means of the nervous system. Through our sense organs we gain our information of the world.

The nervous system is made up of cells which are highly specialized. Their main work is to transmit and interpret stimuli. The nerves of man are so highly specialized that all stimuli which affect the eye are thought by us to be light

stimuli; or all stimuli which enter in the ear, seem to be sounds. The stimulus which passes over any of our special sense organs travels over several different nerve cells before it reaches the place in the brain where it is interpreted. The highly specialized nervous system and sense organs grow and are fed just as muscles or skin grow and are fed. There is no special food which we can eat that is used exclusively by the nervous system.

QUESTIONS

What is the nervous system? Of what parts is it composed? What animals have you studied that have a nervous system? Which ones lack a special nervous system? How does the nervous system grow? Describe the nerve cell. How does it differ from other cells in man? What are special senses? What kind of information do you receive through your eyes? What kind through your ears? Which do you remember? (The well-trained mind remembers equally well the information that comes in through each of his sense organs.)

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Horsley and Sturge, Alcoholism and the Human Body.

CHAPTER XXXV

THE BIOLOGY OF DISEASE[1]

STUDENT REPORT

How many in the class have been sick during the past year? Of how many different diseases? What was done to aid each one in getting well? What was done to prevent others from taking the same diseases? What was done by your Health officer? (Consult the reports of the State Board of Health and of the local health official.)

371. Disease. — Usually people go through their daily occupations without feeling pain or bodily discomfort. Such a condition is known as health. Sometimes, however, they go about their usual duties when they do not feel well and the indisposition gradually passes away. But in other cases the ill feeling becomes severe, the usual activities are given up, and we say that they are sick. Sickness may last for only a short time or for many years. The usual conditions of the body are changed, and we say that the body is diseased. The apple, the tree, the dog, the horse, each has its own diseases.

372. Cause of Disease. — While there are many causes of disease, all of them may be grouped under four headings: (1) Inherited diseases, *i.e.* those transmitted from parent to child, as certain forms of insanity and imbecility. (2) Diseases caused by such poisons as lead, arsenic, mercury, phosphorus, opium, cocaine, alcohol, and the like. The disturbances which these chemical agents set up in animal tissues are easily recognized by a good physician. (3) Diseases which cause certain tissues to take on an abnormal

[1] Chapter XXIII, Bacteria, may be read in connection with this chapter.

growth, as in tumors and cancers. (4) Diseases caused directly or indirectly by some definite living plant or animal. Such diseases are called "biological diseases," because the source or cause is in all instances some definite living plant or animal. In our ordinary daily speech we often speak of such ills as "germ" diseases.

373. Biological Diseases. — The rattlesnake secretes a poison which is forced through fangs or hollow teeth into the blood of its prey. This poison affects the heart and may result in death. One of the common and beautiful mushrooms produces a similar poison which is not destroyed by cooking. If this particular mushroom is eaten, death is almost certain to follow in from twenty-four to forty-eight hours. In both these cases the animal or plant is large enough to be seen and easily recognized.

But there are a considerable number of microscopic plants and a few microscopic animals that have formed the habit of living for at least a part of their life in other plants and animals. During this time, as we have seen in the study of animal and plant parasites, they usually secure all, or the greater part, of their food from the plant or animal in which they are living. Two general causes of disease result from this parasitic habit. The parasite may destroy certain cells of the body, or the material thrown off from the body of the parasite may act as a specific poison.

374. Communicable Diseases. — The term *communicable disease* [1] is used in this book to mean the diseases caused by a plant or animal living as a parasite in plants, animals, or

[1] New York State designates the following as communicable diseases: anthrax; chickenpox; cholera, Asiatic; diphtheria (membranous croup); dysentery, amœbic and bacillary; epidemic cerebro-spinal meningitis; epidemic or streptococcus septic sore throat; German measles; glanders; measles; mumps; ophthalmia neonatorum; para-typhoid fever; plague; poliomyelitis, acute anterior (infantile paralysis); puerperal septicæmia; rabies; scarlet fever; smallpox; trachoma; tuberculosis; typhoid fever; typhus fever; whooping cough.

Professor Theobald Smith (1859-still living) is a technical scientist. Before any physician knew how to prevent disease, technical biologists had to discover how the disease germs live. Such is the work of Professor Smith, and he is an acknowledged authority in his field.

His best known discoveries are as follows: 1. He discovered that the protozoan parasite in the blood of cattle which causes Texas cattle fever is also found in ticks. It is carried from one cow to another by the infected ticks. This discovery led to similar discoveries in Malaria, Sleeping Sickness, and other protozoan diseases. 2. His scholarly researches in human tuberculosis have been of great value to mankind. 3. Present standards of meat inspection are based upon his investigations into the diseases of cattle and other food animals. 4. He was a pioneer in the manufacture and extensive public use of antitoxin.

man. These diseases are communicated in various ways from one individual to another, from one animal to another, or from one plant to another.

The following are among the most common communicable diseases. Diseases caused by bacteria (minute plants) are tuberculosis, pneumonia, diphtheria, typhoid fever, bubonic plague, and whooping cough. Measles and scarlet fever are so similar to these in many ways that it is believed that they are caused by bacteria, although the definite bacteria which cause them have not been discovered. Diseases caused by protozoa (minute animals) are malaria, yellow fever, sleeping sickness, possibly smallpox, and others less well known.

The biological diseases are all preventable, especially the communicable diseases which result from the parasitic habit of some plant or animal. In order to prevent these diseases, it is necessary to know how the different plants and animals gain access to the human body and proceed to live there. This can be illustrated by describing pulmonary tuberculosis, a plant or bacterial disease; and malaria, an animal or protozoan disease.

375. Pulmonary Tuberculosis. — Pulmonary tuberculosis is a disease located in the lungs. The cause is a definite plant with parts and habits which are easily recognized by bacteriologists (students of bacteria). This plant is called *Bacillus tuberculosis,* and was proved to be the cause of consumption, or tuberculosis, by Robert Koch, a German scientist, in 1882. These tuberculosis bacteria, or germs, in countless numbers are found leading a parasitic life in the lungs of a tubercular patient. The bacteria are extremely minute, and can be seen only by the use of a microscope of high power.

The large number of germs in the lungs grow rapidly and they are set free in the air by coughing. One tuberculosis patient may give off millions of these germs in a

day. For this reason great care should be taken in destroying the sputum of patients, for if the germs become dry, they are carried about as dust particles.

Tuberculosis and other disease germs are so numerous that it is impossible to escape taking some of them into our bodies, but they usually do us no harm unless we are in a weakened condition.

Modern methods of cleaning the streets by flushing with water, keeping garbage covered, and wiping up the dust

FIGURE 424. — TUBERCULOSIS CURE, SUMMER.

in our homes instead of using the old-fashioned feather duster are doing much to keep down the number of germs in the air which we breathe.

The bacteria that are breathed in from the air may find some weak place in the lungs in which to take up their parasitic lives. Those which enter on the food pass from the digestive tract into the blood and are eventually carried to the lungs. The introduction of tuberculosis germs in

this way is especially frequent in children. In many cases milk from the tuberculous cows is the source of the germs.

The cause of pulmonary tuberculosis is, then, the tubercle bacillus, which is taken into the lungs in the air we breathe, or through the food eaten, or by personal contact with a consumptive patient. These germs cause certain parts of the lungs to become diseased.

376. Getting Well. — Consumption is not necessarily fatal, especially if treated in its earliest stages. But many

FIGURE 425. — TUBERCULOSIS CURE, WINTER.

people who have the disease do not consult a regular physician until it has made considerable progress, and then it is too late to bring about a cure.

Figures 424 and 425 show the present method used in treating tuberculosis. The patients are given tissue-building food (protein) and are required to sit and sleep out-of-doors as much as possible. Rest, good food, and fresh air work wonders in arresting the progress of this disease.

When the body gains the requisite amount of strength the disease and its germs are usually thrown off. Patent medicines and alcohol should be avoided, as they reduce the power of the body to resist disease and give no aid in building up the diseased tissues. In addition, alcohol causes serious disturbances in the general circulation.

In addition to pulmonary tuberculosis physicians recognize tuberculosis of the throat, intestines, kidneys, brain, and joints.

377. Influenza. — This is a communicable disease that killed more than 550,000 people in the United States during the fall of 1918 and the winter of 1919, which is about five times the number (111,179) of American soldiers officially stated to have lost their lives from all causes in the World War up to the date of April 30, 1919. This disease is contracted only by those who come in contact with the secretions from the nose or bronchial tubes of one who is affected with it. The word contagious is properly used for such diseases, because the person suffering from them gives off germs that pass to another. In this same sense tuberculosis, diphtheria, and typhoid fever are contagious diseases.

When the disease is of average severity the symptoms are a chilly sensation, headache, and "bone ache," or pains all over the body, and fever. Coughs usually develop as the progress of the inflammation extends into the bronchial tubes. The full force of this disease may center in the respiratory organs, or in the muscles and nerves, or in the digestive tract. It is clear that influenza paves the way for pneumonia, if it does not actually produce it.

The mouth and nasal passages should be kept clean with such washes as salt in water or borax in water in the proportion of one level teaspoonful to a pint of water. The chief value of all nasal washes is the water, and any preparation that has a smarting reaction should be avoided. There is really no special method of cleaning the nose that excels

the natural method, *i.e.* blow it, and blow it into a paper napkin and burn the napkin.

This disease spreads in epidemic form about once in a generation throughout the earth along the routes of travel, and is carried from place to place by man. The name *Influenza* was given to it in Italy about one hundred years ago, because it was supposed to be due to the influence of some malevolent agent of the air. The French term "*La Grippe*" is given to this same disease; while the expression *Spanish Influenza* simply means that the 1918 epidemic started in Spain or was first noticed in epidemic form in Spain.

Home Report. — Look up the ravages of influenza in India, Alaska, etc.[1] See what you can find out about the total number of deaths in the different nations of the world.

378. Malaria. A Protozoan Disease. — Malaria is a disease caused by a protozoan or minute animal which is distributed over the greater part of the world. The malaria protozoön is a minute simple cell of living matter. It resembles the amœba in its form and ability to change. This parasite penetrates into the red blood corpuscles and remains in them for twenty-four or forty-eight hours, or until the substance of the corpuscle is nearly used up. Then the parasite escapes into the plasma of the blood and later enters a fresh corpuscle.

379. Source of the Malarial Parasite. — The word malaria means bad air, for it was formerly believed that foul air caused the disease. When it was learned that a definite animal was the cause both in man and in other animals, the problem was to find how the parasite entered the body. It has been proved to the satisfaction of scientists that the malarial protozoön is injected into the blood by a particular kind of mosquito (Anopheles) which carries malaria germs in its body. (See page 55.)

[1] Influenza Studies by Raymond Pearl. Reprint No. 548, Public Health Reports, Treasury Department.

The mosquito sucks the blood from a man or an animal suffering from malaria. This blood contains some of the malarial parasites, which pass into the stomach of the mosquito. They then migrate into the salivary glands of the mosquito, so that as soon as the mosquito bites another man or animal, it pours out some saliva which introduces the parasites into the victim's blood. While in the body of the mosquito, these parasites pass through definite stages in their life history; and when they reach the blood of man, the remaining stages are completed. Thus a man, or an animal, and a particular mosquito are necessary for the complete life history of the malarial parasite.

This means in addition that for the prevention of malaria all that is necessary is to prevent the Anopheles mosquito from breeding, or in case this cannot be done, to screen adequately the houses, tents, and bedrooms in the regions where the mosquitoes live. It is interesting to note that the methods for the prevention of malaria were more than anything else responsible for the successful completion of the Panama Canal. The construction of this important work thus became a health as well as an engineering problem.

380. Other Protozoan Diseases. — Other protozoan diseases are produced in the same manner as malaria. The carrier may be different, but the principle of spreading the diseases is the same. Yellow fever, for instance, is spread by another kind of mosquito, and sleeping sickness by the tsetse (tsĕt′se) fly. (See page 55.)

381. Hookworm Disease. — This disease is caused by a parasite which is classified as one of the worms. Hookworm disease belts the earth in a zone which extends thirty-three degrees each side of the equator. Great progress is being made in the United States in curing those suffering from this disease. The wearing of shoes and the use of a sanitary closet are usually sufficient preventives to protect the people who live in a hookworm district.

The worms that cause trichinosis are closely related to hookworms. This disease is due to the round-worm, trichinella, and comes from eating partly cooked pork that has these worms in the flesh. This is becoming a rare disease, due to the painstaking inspection of slaughter-houses by the government. Flat tapeworms are often found in dogs, cats, and fish. Occasionally one gains access to the intestinal tract of man. Here it rapidly grows into the adult stage, living upon the food that should go to nourish man.

SUMMARY

Disease prevents us from working as we do when we are well. Most diseases are unnecessary and preventable, especially those which are caused by plants or animals living as parasites in our bodies. In most of the biological diseases some definite poison produced by the parasite is taken into the body, and this is the chief cause of disease. Tuberculosis, the "great white plague," is caused by a plant named *bacillus tuberculosis* and often referred to by physicians as "Tb." One can get well if the body is able to overcome the poisons secreted by these minute plants. Each disease caused by bacteria has its own special history and the symptoms of the disease are definite and distinct. Influenza is probably a germ disease, but the exact kind of bacteria is still unknown. It was epidemic over nearly the whole world in 1918 and 1919. Malaria is a disease due to a protozoan parasite living in the blood corpuscles of man. These parasites are introduced into the blood through the bite of Anopheles mosquitoes.

QUESTIONS

What are the biological diseases? How are these diseases caused? How many kinds of tuberculosis are there? Is diphtheria a germ disease? Are colds germ diseases? Describe malaria. What effect has malaria had upon the settlement of our country? This is a home study question.

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CHAPTER XXXVI

PREVENTION OF DISEASE

382. Preventable Disease. — More than 600,000 lives and more than a million dollars are wasted in the United States each year by preventable disease. For this carelessness and ignorance are chiefly responsible. Preventable disease can be practically wiped out by vigilance, cleanliness, and wholesome living, in short, by *sanitation.*

Prevention of Communicable Diseases. — The prevention of these diseases depends upon an understanding of the causes which produce them, close adherence to the laws of hygiene, and especially the exercising of proper care in the production and cooking of our food. Germ diseases are unnecessary, and it should be considered a disgrace to a community if some of them appear.

Proper hygienic measures will do much towards eliminating most of the communicable diseases, but until the intelligence of communities can be aroused enough so that such measures shall be insisted upon, we must depend upon proper food, rest, fresh air, and exercise to keep ourselves fit, and thus avoid the conditions which help disease to gain a foothold. Tuberculosis, for example, is more likely to occur in persons who are underfed and overworked, and a cold often follows an attack of indigestion.

Care of Food. — The care of food is extremely necessary in preserving our bodily well-being, for the same germs live and grow in food which cause disease when taken into our bodies. One method of keeping the bacteria on food from growing is by proper refrigeration. The temperature

of a well-cooled refrigerator does not destroy the germs, but makes them incapable of growth until heat is supplied them. If food is taken from the refrigerator and allowed to stand for a time, the bacteria will at once begin to grow and cause the food to spoil. If such food is eaten, an intestinal disturbance usually results.

In the attempts to prevent disease, more study has been given to milk and water than to other necessities. For discussion of milk, see pages 313–315.

While milk is used as a food by all mankind, water is even more important, for it is absolutely necessary if we are to continue to live. In this respect man is like all plants and all other animals, water being necessary for the preservation of all life.

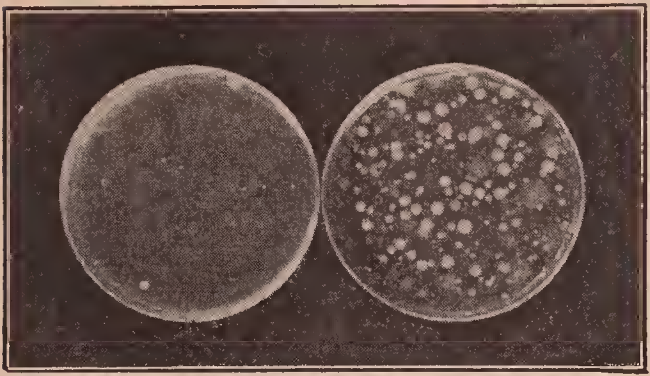


FIGURE 426. — MILK DILUTED TO $\frac{1}{1000}$.

Left-hand culture from clean milk; right-hand culture from dirty milk. Count the number of spots in each plate and multiply by 1000 and you will have some idea of the difference between clean and dirty milk. Certified milk is almost free from bacteria.

Two conditions must be met before a water supply can be deemed satisfactory. There must be an abundant supply; but more important still, the water must be *pure*, that is, free from disease-producing germs. Farmers and residents of small towns may without great trouble secure sufficient pure water, but the large cities have to spend millions of dollars in providing an adequate water supply.

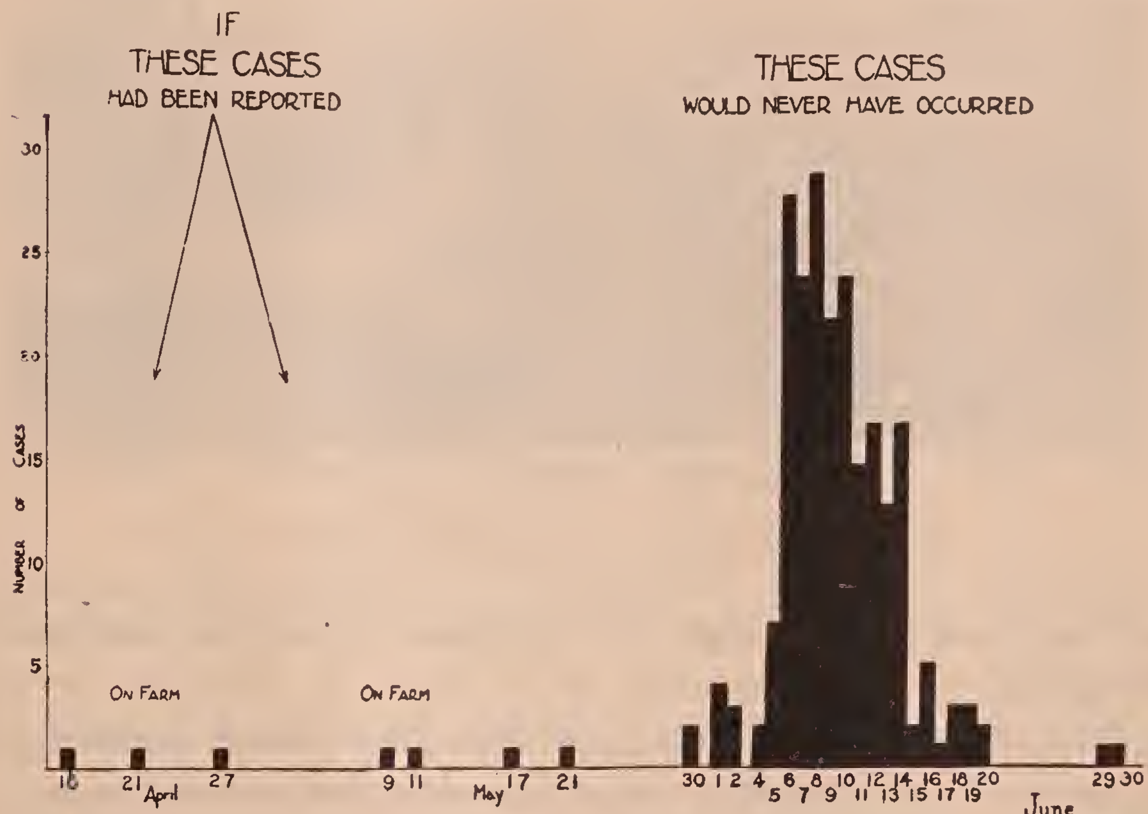
Sanitary measures are adopted to keep the sources of the water from becoming impure, as well as to keep clean the reservoir where it is stored. Certain harmless plants and animals living in reservoirs may give an unpleasant taste or odor to the water. Harmful disease germs live in water for months. Such germs may be frozen in ice,

stored in ice houses, and when later put with the ice into drinking water, may cause typhoid fever. It is, therefore, important that we have plenty of pure water, and we should do all we can to help in giving the town or city in which we live a pure water supply.

STUDENT REPORT

Prepare a report on the water supply in your locality and find where it comes from. What measures are taken to keep the sources and reservoir clean?

383. Keeping Well. — Our best doctors are spending much effort in showing how to avoid disease, for no one is benefited by illness. The old notion that children should



THE STORY OF THE EPIDEMIC OF SEPTIC SORE THROAT AT ROCKVILLE CENTRE, L. I.

FIGURE 427.

be exposed to measles, scarlet fever, and whooping cough is wrong, for none of these childhood diseases is necessary. The time will come when our homes and surroundings will be so sanitary that the common diseases caused by germs will be eliminated, or at least decreased in number.

Government inspection of meats is lessening the amount of disease contracted from eating diseased pork, other meat, and fish. The United States Department of Agriculture is making every effort to inspect such products, and the department is fairly successful in inspecting the larger establishments. Many cattle and hogs, however, are killed and sold locally and they escape inspection, so that buyers

FIGURE 428. — MALARIAL SWAMP.
An ideal place for mosquitoes to breed.

of this meat have no protection against a general condition of disease.

Another danger to health is from the people known as "carriers" of disease, as such people give no evidences of illness. Typhoid and diphtheria are the two diseases most likely to be carried in this way. Many of these carriers serve as cooks, and as they give no evidence of being in other than perfect health, they often spread the germs through the food they prepare. If habits of absolute cleanliness are insisted upon, much of the danger of the dissemination of germs in this way may be removed.

Many hotels, public institutions, and well-run households insist that a prospective servant shall be examined by a competent physician before being engaged for work. In this way carriers may be detected, and persons with germ diseases, like tuberculosis, for instance, are prevented from spreading disease either in the food or in the air.

Children in the schools frequently have diphtheria germs living in their nasal passages or throats, but are not ill. After a time a number of children are stricken with the disease. A doctor then takes a sample of the contents of the throat and nose of each child. The bacteria in the mucus from the nasal passages are allowed to grow for twenty-four hours in a special preparation called a *culture* (page 312). At the end of that period the cultures are stained and examined with a high power microscope, and if diphtheria germs are present, they are easily seen. If one of the well children has these germs, he is treated until they disappear.

384. Quacks and Patent Medicines. — The term *quack* is applied to a person who pretends to skill or knowledge which he does not possess. Technically, a *patent medicine* is a medicine whose composition is a matter of public record, and for which letters-patent have been granted which give the patentee the exclusive right to the manufacture and sale of this product for seventeen years. Colloquially, however, a "patent medicine" is a remedy, usually secret in composition, to which a fancy name has been given and that name trade-marked. Such a trade-mark gives to the owner a perpetual monopoly on the name while it imposes no restrictions on the composition of the product that goes under that name. Most so-called patent medicines are of the latter type and are really not patented at all. Many millions of dollars are spent annually in advertising special "cures" and mechanical contrivances guaranteed to cure diseases for which they can do nothing, or even to cure such diseases as cancer, tuberculosis, epilepsy, etc.

Many people who do not understand the causes of disease are reluctant to consult a well-trained physician, but read and believe the carefully worded advertisement of some quack doctor or of some patent medicine. The untrained sufferer cannot interpret the meaning of his distress and is incompetent to select the proper medicine.

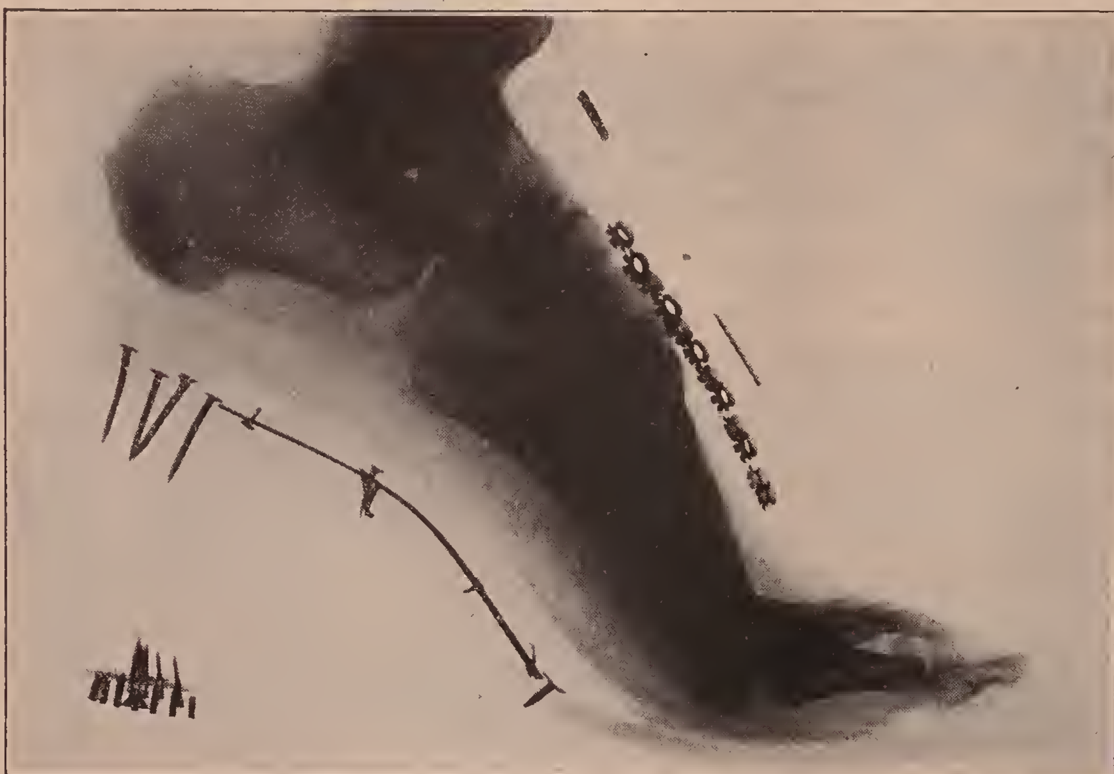


FIGURE 429. — X-RAY OF THE FOOT OF A GIRL WEARING A HIGH HEEL SHOE.

The many layers of leather in the heel were fastened by means of glue. Notice the effect of raising the heel so high. It weakens the muscles on the back of the heel and places an unusual strain on the muscles of the arch of the foot. The wearing of such shoes is the source of much discomfort and is just one illustration of what one should not do who wishes to keep well. Compare with Figure 430.

As real medicine is given for specific symptoms associated with a specific disease, it is apparent that a patent medicine advertised to cure from six to forty diseases is worthless. Furthermore, real medicine is given to relieve a certain set of symptoms at a given stage of the disease, and is frequently changed. This is, of course, impossible when using a patent medicine. If every one would consult

regular physicians, and cease patronizing the quacks and patent medicines, one of the sources of much sickness and suffering would be destroyed.

Our government through its enforcement of the Food and Drugs Act is doing a great deal to protect those who do not understand about disease and its cure. This Act is too limited and should be revised and its scope broadened; for

FIGURE 430. — X-RAY OF THE FOOT OF A GIRL WEARING A SENSIBLE SHOE.

Note how differently the pressure comes on the parts of this foot as compared with that shown in Figure 429.

we find since its passage that there has been an increase in the number of remedies sold as "cures" for epilepsy. The main drug in these fakes is bromide of potassium, which is harmful to the patient, especially in the large doses recommended. While this drug has the power to suppress temporarily the epileptic attack, it leaves the sufferer in a worse condition.

The number of "deafness cures" is legion. The middle and inner ear, where all diseases of the ear are located, is separated from the brain by a thin partition of bone and it

is extremely dangerous to permit quacks to tamper with such a delicate organ as the ear. At the present stage of our scientific information, very little can be done to cure deafness. By writing to the American Medical Association, Chicago, Ill., you can secure much information about alleged cures for deafness as well as about patent medicines and mechanical contrivances.

Woman's fashions during the past few years gave a wonderful stimulus to the exploiters of "obesity cures." The desire to be slender — often far beyond what is compatible with good health — caused thousands of women to waste their money on so-called reduction treatments that were either dangerous or worthless or both.

Thyroid extract was the basis of many of the "fat reducers" first put on the market, and this drug is still somewhat in use. We are all beginning to realize that this is a dangerous drug, so that other things have had to be substituted. A very common sea-algæ, the kelp (Fucus vesiculosus), has been used in many of the fat-reducing preparations. It is difficult to find out why this plant is so popular because in some localities farmers have used it as food for their hogs in the belief that it makes them fat. Overeating and too little exercise are the chief causes of obesity. Remove the causes and stop buying fakes.

Between the ages of twelve and eighteen usually, nearly all children have pimples, especially on the face. There is no remedy that will prevent them. The same can be said about the tendency of those of light complexion to sun-burn or freckle, only here there is no age limit. Catering to the ignorance and pride of girls especially, fakers advertise numerous cosmetic preparations for the skin, hair, etc. Many of these have been analyzed by the chemists of the government and found to consist of borax, starch, epsom salts, soap, and other common substances which cost from one to three cents a bottle and for which the user pays fifty cents a bottle.

Testimonial letters stating that the writer has been greatly benefited by a given patented preparation or mechanical contrivance are abundantly used by all fakers. An official of the United States Postoffice once wrote: "Speaking generally it may be said that in all my experience in this office never has a medical concern, no matter how fraudulent its methods or worthless its treatment, been unable to produce an almost unlimited number of these so-called testimonial letters." An investigation by the American Medical Association has shown that some of these letters are purchased, some written in the office of the "patent medicine" concern, and some actually written in good faith. Those who write the letters in good faith are relatively few in number and nearly always ignorant and unable to judge accurately of the cause of their trouble. Many of them after writing of the benefits are found to be just as deaf or epileptic as before taking. In the case of consumptives who write of being helped, it is only necessary to wait a few months and the death certificates are available as silent testimonial to the fake.

As the United States Government has been more and more successful in prosecuting the ordinary frauds, the propagators of fakes have become more skillful, especially in the false-scientific manner of advertising.

The following is from "*The Nostrum and the Public Health*," an article published in the Journal of the American Medical Association, May 24, 1919, written by Arthur J. Cramp, M.D.:

"The physician, of course, is opposed to the average 'patent medicine' because it is exploited in such a way as to cause the public to magnify its trivial ailments, to drug itself unnecessarily and in cases in which something serious is the matter to lose vitally valuable time in seeking medical aid. . . .

"Unfortunately, the home remedies of to-day are, generally speaking, 'patent medicines'; and the methods of promoting

the sale of patent medicines make those products a menace to the public health. This not altogether for what the remedies themselves contain, although in many instances that is distinctly bad, but because of the way such products are exploited. . . . So to advertise as to make well men think they are sick and sick men think they are very sick, for the sole and only purpose of causing them to purchase drugs to pour down their throats, is more than an economic offense; it is a crime against the public health. Yet this is the principle on which the average 'patent medicine' of to-day is sold."

Students of even such an elementary course of biology as this, possess the needed information to enable them to tell the difference between fakes and real remedies. This is one of the important results that you should obtain from this study. Learn to seek for the real cause of disease and be certain that the results which follow are due to the medicines taken before writing testimonials for fake cures.

385. Alcohol in Patent Medicine. — Many patent medicines contain a considerable amount of alcohol. Since the passage of the national Food and Drugs Act, which went into effect January, 1907, the presence and quantity of alcohol in "patent medicines" has to be declared on the label. This alone tended to reduce the amount of alcohol in many of them but there still remained a large number of preparations whose most active and powerful drug was alcohol. Some of these were so slightly medicated that the United States Government would not permit them to be sold except under a liquor license. Since the advent of prohibition, of course, these can be sold only under the strict regulations governing the prescribing of alcohol.

Some patent preparations contain also cocaine or opium and should not be taken for this reason.

386. Alcohol and Disease. — It is unnecessary to make an elaborate series of quotations from eminent men to prove

that alcohol is not useful and necessary as a medicine in the cure of disease. One of the chief reasons has already been given in connection with the discussion of tuberculosis. There is no evidence that alcohol has any effect on the destructive course of a disease, or any beneficial effect upon the person suffering from disease. This last phase of the problem has been under critical study long enough to show that the earlier claims of the helpfulness of alcohol in disease are not supported by the facts. The reverse is true. Alcohol is known to decrease the power of the body to withstand disease and does not assist in destroying the poisons which arise in the case of bacterial diseases. At present there is no scientific evidence which justifies the use of patent medicines, or of alcohol unless definitely prescribed by a physician.

387. Headache and Anti-pain Patent Medicines. — Many preparations advertised under these general names are taken by persons ignorant of the fact that these medicines generally contain harmful drugs. It should be sufficient to know that no reputable doctor will ever give any of these preparations except in a mild form, and in case of extreme pain. No person except a trained physician has a right to prescribe drugs; and he only after a knowledge of the patient's symptoms. Many of these preparations affect the heart and blood, and none of them has any beneficial effect on the real cause of the pain.

388. Boards of Health. — Communities and physicians have endeavored to prevent the spread of communicable diseases by the formation of boards of health, by quarantine, vaccination against smallpox, immunization against typhoid fever, the use of antitoxin in diphtheria, disinfectants and fumigants.

The term *Board of Health* is applied to a number of individuals, appointed or elected by a nation, by a state, or by a municipality, to enforce the national, state, city, or town

health laws and regulations. The local officer of this board is a physician, and in some states, New York for example, is appointed according to the regulations governing the city or town in which he is to serve. The New York state law defines his work as follows:

"Every such local officer should guard against the introduction of such communicable diseases as are designated by the State Department of Health by the exercise of proper and vigilant medical inspection and control of all persons and things infected with or exposed to such diseases, and provide suitable places for the treatment and care of sick persons who cannot otherwise be provided for."[1]

Violation of quarantine and of the various health regulations, such as the pollution of water and improper care of refuse and sewage, should be reported to the local health officer. In case no satisfactory results are obtained from the local health officer, the question may be referred to the State Board of Health, which gives prompt and efficient attention to all questions concerning the health of the people of the state.

389. Quarantine. — When a person or a group of persons is suffering from a communicable disease, or when anyone has been exposed to the germs of any such disease, the Board of Health may place him under *quarantine*. The nature of the quarantine depends on the specific disease and the laws of the town or state in which the disease is prevalent.

The New York law on this subject is typical of the best state laws on quarantine. It says:

"The Board of Health shall prohibit and prevent all intercourse and communication with or use of infected premises, places, and things; and require, and, if necessary,

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[1] The Sanitary Code of the Public Health Council of the State of New York defines the health officer's duties in detail and may be had by writing to the State Department of Health at Albany.

provide the means for the thorough purification and changing of the same before general intercourse with the same or use thereof shall be allowed."

This means if an individual is suffering from scarlet fever or diphtheria, or some other communicable disease, he shall not associate with the general public until he has ceased to be a source of infection. His liberty is temporarily restricted by quarantine because he may be the cause of sickness and even death to others by spreading the germs of communicable disease.

It is interesting to know that the more highly civilized a nation, state, or city becomes, the more specific and exacting are the quarantine regulations. There is every reason to believe that in the near future the present laws of quarantine will be extended. In addition to individuals being quarantined in a dwelling, all the inhabitants of a city or state may be quarantined in case of severe epidemics; or the transportation of stock from one state to another may be prohibited in the case of a serious communicable disease existing in cattle or sheep. The quarantine laws, for example, order from time to time that all dogs in the town or county shall be muzzled as a protective measure against rabies.

Immigrants suffering from certain diseases are prohibited from landing in the United States. This means that there are national as well as state and city quarantine laws. The present quarantine laws are the most effective protective measures against the spread of disease known to man and are the product of a high degree of civilization.

390. Vaccination. — The success which has attended the efforts of man to overcome disease is well illustrated by smallpox. For centuries this disease was responsible for many deaths throughout the world. It is said to have existed in China centuries before Christ. Later it swept over Europe again and again. A famous French physician

wrote in 1754 that every tenth death was due to smallpox, and that one fourth of mankind was either killed by it or disfigured for life. Smallpox was brought into the Western Hemisphere soon after the discovery of America and killed thousands of the Indians. It also affected the colonists. In 1721, Boston was ravaged for the sixth time by this disease. Out of the 10,567 inhabitants, 5989 had the disease and 894 died.

In 1796, Jenner, an Englishman, demonstrated the fact that by inoculation of a person with cowpox, a disease peculiar to cows and in some way allied to smallpox, the patient would become immune to the dreaded disease. This was one of the greatest and most beneficial discoveries of medicine which has ever been made.

As the result of vaccination and sanitation smallpox has become a rare disease in the civilized nations of the world, and is least prevalent where the vaccination laws are the most stringent.

Vaccination for smallpox consists in the inoculation of the human patient with vaccine, a substance secured from a cow suffering from cowpox. This usually causes a slight illness, but during the illness the patient acquires a power which enables him to resist the germs of smallpox. This acquired power of resistance is called immunity. Immunity secured through vaccination or through having a disease, such as whooping cough for example, is described as *acquired immunity* to distinguish it from that form of immunity to all diseases or to certain diseases which many people possess. This latter is *natural immunity*. Those in the class who have not had measles may be said to have a natural immunity against measles. Those in the class who have had measles once have an acquired immunity against measles.

Many people do not understand the theory of vaccination and its advantages, and have opposed its use through

fear of acquiring lockjaw from the vaccine. It has been established that proper vaccine matter never contains the germs of lockjaw, and if this disease then occurs, it is due to failure in keeping the arm clean during the period when the vaccination scar is forming.

Immunity to disease is now being produced through inoculation. The patient is inoculated, that is, there is introduced into his circulatory system a virus, or serum. Each disease has its own virus, as the vaccine in smallpox, and this virus produces a mild form of the disease. This causes the cells to become resistant to the germs or microbes of the specific disease. Inoculation is being widely used for the prevention of typhoid fever. All soldiers are required to take this treatment. It would be desirable for all people to become immunized against this disease, but those who travel extensively and thus have to drink all kinds of water and milk should certainly undergo this treatment.

Vaccination and immunization reduce the liability of death in case the disease is acquired, but they do not absolutely prevent the disease. If a vaccinated or immunized person gets an overwhelming number of germs, he may have an infection of a slight kind. But the liability of contagion is reduced to a minimum.

391. Antitoxin. — We cannot say definitely why vaccination and immunization act as they do. It is known that if a poison (toxin) produced during a case of diphtheria is gradually introduced into the blood of a horse, a substance is produced which destroys the injurious effects of the diphtheria poison. The serum from the blood of the horse is called antitoxin, and may be preserved for use at any time to destroy the influence of the diphtheria poison. A given amount of this antitoxin is introduced into the blood of the patient suffering from diphtheria, and usually counteracts the poison of the disease. This treatment has saved countless lives. It is estimated that in the ten years

following the discovery of the diphtheria antitoxin the lives of a million children were saved in France alone. State boards of health usually furnish antitoxin for diphtheria and lockjaw.

LABORATORY STUDY

It takes five pounds of sulphur to disinfect a room which contains 1000 cubic feet of air. Three ounces of forty per cent formalin, to which is added two and one tenth ounces of potassium permanganate, will also disinfect the same sized room. Compare the cost and ease with which each is used.

392. Disinfection and Disinfectants. — The time when disinfectants shall be used and the manner of disinfection have been considered important factors in preventing the spread of communicable diseases. The purpose of disinfection is to destroy the germs lodging on clothes, floors, carpets, and curtains. People who care for the sick should know where the germs are likely to be and how to disinfect places where they have found lodgment. The term *disinfectant* is sometimes incorrectly applied to deodorizers, substances which are used to destroy odors, but the word should be applied only to substances which destroy germs or bacteria.

Disinfectants are not expensive, and few of the patented preparations are as satisfactory as the common ones used by boards of health. Weak solutions of carbolic acid and bichloride of mercury are chiefly used for killing the germs on the hands and clothing, or for cleaning the woodwork in the sick room. Chloride of lime is used to kill the germs in the discharges of the body, and sulphur dioxide and formaldehyde gas for the final killing of the germs in the room or the whole house before it is occupied again.

Never use any methods of disinfection unless they have been personally recommended to you by a physician or an expert in the details of room disinfection. Do not rely

upon patented solutions and methods. The latter are expensive and often practically worthless.[1]

393. Save the Children. — The care which animals take in the protection of their young is one of the most fundamental instincts of their nature. But in civilized man his instinct is broadened and controlled by the power of reason and a knowledge of the laws of hygiene. Until man came to understand these laws, many of his efforts to protect his young were of no more avail than the brave fluttering and plaintive cries of a bird when a red squirrel is robbing her nest.

During the last decade there has been an attempt to reduce deaths among children. It is lower in America than in most countries of the world, in which fact we take pride. The state of New York has the lowest death rate among children of any state in the world of which we have accurate knowledge. Yet there are communities in this state where the waste of infant life is a disgrace to civilization. The centers where this high death rate exists are largely populated by foreigners whom we permit to live in unhygienic conditions.

In a study of 9912 deaths among infants in New York State for the year 1916, over 55 per cent of these died from measles, whooping cough, bronchitis, pneumonia, bronchopneumonia, and infantile diarrhea. All of these are due in large part to parental ignorance concerning the elementary facts of sanitation and the proper care and feeding of infants. The infantile mortality among the foreign-born mothers is much greater than in the native white mothers. Particularly high death rates prevail among the Polish, German, and Austrian mothers.

It is difficult properly to measure the value of health to the community. When the wage earner is sick and is placed

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[1] When practicable, it is well to have the local health officer discuss such subjects as disinfection and quarantine.

in quarantine, the loss of money is the amount he might have earned. In the case of a typhoid fever epidemic the total loss is many thousands of dollars. Further, there is no adequate measure of the sufferings of those who die and the heartaches of those who survive. But both the suffering and the financial loss can be greatly lessened by improving our sanitary laws and aiming at a better state of health for all the people. An increase in taxes to provide cleaner streets, public playgrounds, proper sewage disposal, and adequate inspection of milk, meat, and water, is really an economy. For although such improvements cost money, they are not so expensive as epidemics of disease and the maintenance of hospitals and of orphan asylums.

394. Epidemics after Wars. — The return of two million men from Europe after living there for several months, to scatter throughout the United States, raised public health questions of great interest. After the Crimean War (1854–1856), cholera was epidemic in France and England; after the Franco-Prussian War (1870–1871), smallpox was epidemic in England, Germany, and Austria; after the American Civil War (1860–1864), typhoid fever spread to many of the northern cities; and after the Spanish-American War (1902), typhoid and smallpox were very common. These historical facts show that there has been great danger in the past from returning troops.

The officials in the army and navy thoroughly understood the dangers and tried to take proper precautions against the spread of disease; but the task was very great. Some of the epidemic diseases in Europe were of the types which, once well started, might produce great havoc. They included trench fever, typhus, relapsing fever, cholera, and plague. Most of these are transmitted by vermin, most commonly the louse. In general the conditions are not favorable in the United States for the transmission of disease by lice, although in certain congested quarters they are common.

The term *epidemic* as used in this paragraph refers to the widespread occurrence of a disease in which a large number of people in a community are affected at the same time. This is the usual sense in which it is used by physicians.

All American troops were detained in Europe at foreign ports for two weeks, during which time they were deloused. After the troops had embarked, they were inspected a second time for lice. On landing in the United States, all the troops were sent to debarkation camps, where universal delousing was practiced.

FIGURE 431. — MALE AND FEMALE COOTIES.

These vermin greatly annoyed the soldiers in the trenches and are carriers of disease. (Much larger than in life.)

Many people think that Americans take so many precautions and are so well trained in ordinary questions of personal and civil hygiene that epidemics are impossible. While many are familiar with the ordinary rules which science has devised for their protection, it requires that all observe them. Those of us who understand the real meaning of communicable disease must take upon ourselves the responsibility of helping to explain the cause of all such disease to those who have not been so fortunate as to have had a course in biology.

395. Prevention of Epidemics. — The first measure to be adopted, and the one of greatest importance, is educational. Under this heading is included the knowledge: (1) that all germ diseases are due to a specific germ, plant or animal, living in an intimate relation on or in the human body; (2) that all germ diseases are preventable; (3) that keeping our bodies clean, eating clean food, well cooked, and taking plenty of exercise will do more to prevent germ diseases than anything else.

The second important measure to be adopted to prevent an epidemic *after the communicable disease has appeared* is the prompt quarantine of the first cases and immediately putting into operation the regulations of the Board of Health for communicable diseases.

396. Heredity of Disease. — The term *heredity of disease* is one which has been misunderstood by many people. By the term *heredity* we mean that which is handed on from parents to their offspring. In the case of biological diseases which are caused by some definite plant or animal, it is evident that they cannot be inherited. But when the parents are afflicted with a biological disease, their bodies become weakened and their offspring may have a poor constitution so that they are more easily affected by disease.

397. Immunity. — *Immunity* is a technical term which means that the body resists or is not susceptible to the germs of biological diseases. Many persons do not become sick when there is an epidemic of typhoid fever, measles, malaria, or the like. Such persons are said to possess a high degree of natural immunity to disease germs. People usually well frequently take germ diseases when the body happens to be exhausted by care or work. In such cases the immunity of the body has been weakened. Many of the germ diseases confer immunity against a second attack of the same disease, but this does not hold true for all persons or for all germ diseases. Vaccination against smallpox, in the case of most persons, confers immunity for about seven years. Inoculation with the typhoid serum confers immunity for from two to three years. Immunity, then, is a relative term, and depends in a large measure on the state of health of the individual and on his power of resisting the poisonous effects of disease germs.

Some idea of loss of immunity is gained from a study of the increase in tuberculosis by Homer Folks, *War, Best Friend of Disease*, in Harper's, March, 1920.

STUDENT REPORT

DUE TO SOME PLANT OR ANIMAL			TREATMENT BY			PREVENTED BY				
	In the water	From contact	Nature	Medicine	Antitoxin	Personal care	Quarantine	Boiling the water	Fumigation	Killing flies
Cold			X	X			X	X	X	
Measles . . .										
Whooping cough										
Typhoid fever .	X	X	X	X	X	X	X	X	X	X
Tuberculosis . .										
Add others . .										

398. Public Parks and Baths. — With the rapid growth in population of cities, more and more people are concentrated in limited areas. The trees are removed from the streets and the buildings crowd close to the sidewalk, preventing the growth of even small plots of grass. To offset this great disadvantage, cities have set apart parks, where trees and grass can grow and where those who cannot get to the country may have contact with nature.

Closely associated with the parks is the public bath, which is a large " swimming pool " where all may have a chance for refreshment and play. A certain amount of play is not only desirable, but necessary, if one is to maintain the vigor of health. These two features in the life of our cities are very useful in helping to keep people well. There are a number of other reasons why public parks and baths are desirable. What are they?

399. Preventive Measures against Sickness. — Now that people have come to understand some of the real causes of disease, they feel that they should do everything possible

to prevent it. A great deal of progress has been made and some states are far in advance of others in prevention of disease. We have really made only a beginning in this direction and by the time that you have become men and women many additional measures will be in operation to assist you and your children in keeping well. Reference has already been made on page 513 to some of the efforts that are being made in New York State to save infants from dying of preventable diseases. This is known as the Child Welfare Movement. What can you find out about this movement in your community? In this connection you should know about the work of the city or county bacteriologist and the health officer.

The following notes were taken from the annual report of one of our New York State cities: In the bacteriological office 10,872 diphtheria cultures were made; 399 examinations of blood, and 1293 cultures of the sputum of patients with suspected tuberculosis; 3073 chemical and bacteriological analyses were made of milk and 215 of cream. The drinking water of this city received repeated study, as the 630 tests for *bacilli coli* indicates. There were 176 inoculations for typhoid and 973 miscellaneous studies. This does not include the work done by the division which has charge of vaccination against smallpox. Not only were the dairies near the city inspected but the more distant dairies were regularly examined.

Closely associated with this technical work in the bacteriology office was the work of the visiting nurse and the school doctor. In this same city nurses visited 3299 homes during the year, and one school doctor made 2477 physical examinations. He found 1845 cases of decayed teeth, 25 cases of poor eyes, and 36 cases of bad tonsils and adenoids.

But the health of the city is cared for not only by looking after the school children but also by inspecting food, and

we find that 31,897 carcasses of meat were passed on during this same year; while sanitary officers inspected yards, barns, cesspools, garbage, stagnant water, and other possible sanitary nuisances to the number of 9308. Learn all that you can about the extent and work of your health department.

Power of Health Officers. — To control communicable diseases is one of the most important duties of a health officer. Says Mr. Joseph A. Warren, of the New York State Department of Health: "When the presence of a communicable disease has reached the proportions of an epidemic, the importance of this duty becomes intensive. From a legal viewpoint the question of the duty of the health officer in such circumstances resolves itself into one of power. A physician may ask: What *should* a health officer do? A lawyer must ask: What *can* a health officer do? The latest decision of the Court of Appeals (New York) holds that where a local ordinance provides for isolation or quarantine in any case deemed necessary by the health officer, then so long as the health officer acts in good faith and has reasonable grounds for his action, his action will be sustained. This situation emphasizes the importance of having proper local ordinances giving the health officer sufficient power."

SUMMARY

As a physician knows the nature of a disease and its effect upon the body, he can aid materially in overcoming the illness. Each biological disease is distinct and must have special treatment. Many of these diseases are taken from some one who has the disease. Vaccination, quarantine, and disinfection are measures which help to prevent the spread of germ diseases. It is our duty to keep well, and we can do much toward this by understanding how to avoid the biological diseases.

QUESTIONS

What is vaccination? What is quarantine? For what diseases are people quarantined? What is the work of the Board of Health? What is the purpose of disinfection? What are the chief disinfectants? What is the danger from epidemics? Name some epidemics. How can they be prevented? What are some of the values of public parks and public baths? What are the powers of health officers? What is your state doing to prevent disease?

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CHAPTER XXXVII

BIOLOGY AND HUMAN PROGRESS

Human progress may be defined briefly as the extent to which man has gained control of his environment and the use which he has made of this control. In a general way our environment has not undergone much change in the last thousand years and yet our control over it has undergone more change during the past hundred years than in any previous thousand years.

This great change is due largely to two factors: (1) scientific discoveries; (2) the intelligent application of these discoveries to the life of all the people.

400. New Discoveries. — Keeping in mind the important fact that our universe has remained about the same during the past thousand years, the natural inquiry is: How can there have been so many new discoveries in recent years? This question can be easily answered. When some one finds a new animal or plant and announces that he has discovered this animal or plant, it simply means that man has seen and described it for the first time. This kind of animal or plant may have been living in this same region for hundreds of years. It is the same when some one makes a new discovery in physics or chemistry. He recognizes relationships that no one else has ever noticed. All new discoveries have been made by men and women who were just boys and girls as you are, with possibly no notion of the way that they were to help to make this world a better place to live in. There is still much to be learned about the relation of plants and animals to human progress and some of

you should prepare yourselves by thorough study to have a part in this great work.

In this chapter a brief account of the value and character of new discoveries in biology will be given. The examples selected, however, serve to show only a small aspect of the whole problem. But they illustrate that human progress, with respect to biology, is dependent upon our knowledge of the intimate life of animals and plants and the general laws governing their activities. These have been outlined in the previous pages of this book. Let us now select a few concrete examples and consider their relation to human progress.

401. Insect Pests. — Most of us never realized how many different kinds of insects there were that feed upon even garden vegetables until we tried to do our part by caring for a war garden. Nearly all the thousands of plant diseases and pests that go to make the life of the farmer, gardener, or orchardist unhappy, and greatly to reduce the size or entirely destroy his whole crop, a few years ago occupied but small territories. So far as our information goes more than one half of the insects that cause incalculable losses in our fruits and vegetables came from foreign countries. They may be said to have migrated to the land of plenty, for in their native homes either the amount of food was limited by the growing of small crops or their natural enemies were so numerous that they were themselves destroyed before they could do any marked damage.

At first thought it seems strange that the government of the United States should have a quarantine against insects landing at our sea ports, but that is just what the Federal Plant Quarantine Act of 1912 means. One department of our government is turning its attention to little insects in order to save American agriculture by preventing any more kinds of insects from entering the United States.

402. Fruit-flies.— Some of these insects of other lands that are serious pests are popularly known as fruit-flies. They

resemble house-flies, but are of more attractive appearance, inasmuch as their wings are prettily spotted and banded and their bodies are usually more brightly colored. They are like house-flies also in that they lay small eggs that hatch into whitish maggots. These maggots feed upon the living tissues of fruits, nuts, and vegetables. Eggs are laid just under the skin of the fruit and these eggs hatch into maggots that burrow in all directions. As the maggots tunnel about they cause decay to develop and these decaying areas produce greater injury than the maggots themselves.

FIGURE 432. — ADULT MALE MEDITERRANEAN FRUIT-FLY (greatly enlarged).

This fly is a cosmopolitan pest. It has been known for one hundred years and during this time has spread throughout the world, North America being the only continent on which it has not become established. This fly does not harm man personally but is one of the most destructive of the fruit-flies.

Increasing imports from the countries where fruit-flies now abound, the extension of trade to remote corners of the earth, and the growing density of population in the warmer parts of our country, are each year increasing the danger that fruit-flies may become firmly established in this country. In order to destroy fruit-flies, the Plant Quarantine Act prohibits the entry of all horticultural products likely to carry insect pests unless they have been rendered free from danger as pest carriers.

The United States Department of Agriculture has issued the following explanation and regulations in connection with fruit-flies: The Bermudas probably would not now be infested by the Mediterranean fruit-fly had not a sailing vessel,

bound for New York from the Mediterranean region during Civil War times, been blown from her course and forced to unload her cargo containing infested fruits at St. George. The Mediterranean fruit-fly did not become established in Australia until steamships and cold storage made it possible for the infested Mediterranean countries to ship oranges to Perth and Sydney. With the pest established in eastern Australia the ships plying between Australia and Hawaii carried the maggots to Honolulu, and to-day the inspectors of the state of California and of the United States are intercepting infested fruits on ships arriving at San Francisco and San Pedro from Honolulu and Hilo.

Figure 433. — Small Mango Fruit Cut to Show the White Larvae or Maggots Which Have Hatched from the Eggs of the Mediterranean Fruit-fly.

These maggots burrow in all directions through the pulp of the fruit, thus rendering it unfit for food. A single fly may lay as many as eight hundred eggs, depositing from six to ten eggs in each fruit. This fly is known to deposit her eggs in seventy-two different kinds of fruits.

Some conception of the extent to which restrictions are placed is gained from the following list: Importations of certain fruits from Mexico are prohibited; also all pines from Europe, and five-leafed pines from Asia, Canada, and Newfoundland; alligator pear seeds from Mexico and Central America; all citrus fruit stock from all foreign countries; Indian corn or maize and closely related plants from India, Siam, China, Malayan Archipelago, Australia,

Dr. L. O. Howard was born at Rockford, Illinois, 1857, and is still living. The year following his graduation from college, he became assistant entomologist in the Department of Agriculture at Washington. He remained in this official position until 1894, at which time he was made chief of the Bureau of Entomology. This position he still holds. He prepared definitions in entomology for the Century and Standard dictionaries. He is the author of *Mosquitoes — How they Live; The Insect Book; The House-Fly;* and many government publications. For many years he has acted as the permanent secretary for the American Association for the Advancement of Science, the largest body of scientific workers in America.

Dr. Howard has devoted his main energies for the past forty years to applying the technical discoveries in entomology to human welfare.

New Zealand, South Sea Isles, Philippines, Formosa, and Japan; sweet potatoes and yams from all foreign countries; banana plants from all foreign countries including Hawaii and Porto Rico.

403. United States Department of Agriculture. — The fruit-fly illustration introduces us to the larger study of the work of the Department of Agriculture and we may begin with one of its subdivisions, the Bureau of Entomology.

During the past forty years Dr. L. O. Howard has been either assistant director or director of this bureau. He and his numerous associates have been making discoveries about insects and applying to human welfare not only the new things that they have been learning about insects but the new discoveries made all over the world.

We may gain some idea of the amount and kind of work done in this Bureau by simply reading over the following subjects, each of which received special study in this Bureau during the year ending August 1, 1917: Work on the gypsy moth and brown-tail moth; deciduous-fruit insect investigations; southern field crop insect investigations; investigations of the insects affecting the health of man; insects affecting the health of domestic animals; cereal and forage insect investigations; investigations of insects affecting forest and shade trees, forest products, and hardy shrubs; investigations of insects injurious to vegetables and truck crops; stored-product investigations; insects affecting tropical and subtropical fruits; bee-culture investigations.

The extent to which man can control the multitude of insect pests and utilize the beneficial insects furnishes a good measure of human progress in this realm of biology.

This outline of the work in the Bureau of Entomology reveals but one of several related fields of activity in which the United States Government is trying to help us gain control of our environment. You should become equally familiar with the other divisions of this work. This your

teacher will show you how to do. Here are the names of these bureaus: The Biological Survey, where they have been giving special attention to seals, reindeer, and ground squirrels; Bureau of Fisheries, which includes not only fish but also clams and oysters as well as lobsters, shrimps, and crabs; Bureau of Plant Industry, dealing with a wide range of problems connected with fruits, vegetables, cereals, and general farm crops; and the Bureau of Chemistry, which takes up such questions as sugar manufacture, various sirups, and adulterations.

Many of the results of the discoveries of the experts working in the United States Department of Agriculture are published as Farmers' Bulletins and can be secured by any one. Write to Division of Publications, Washington, D. C., for the list of available bulletins, which will be sent free so long as the supply lasts.

404. New Ideas. — New ideas keep one informed about the way other people do and make one broadminded and progressive. A different way of weaving cloth, a new process in the utilization of the stored energy in coal, or a better recipe for making bread indicate how a variety of ideas may help man to control his environment. Among the most fruitful sources of new ideas are the numerous scientific discoveries that are constantly being made. Such discoveries are of no value to the masses of the people unless they are turned to practical use.

New ideas are rejected by many people because they do not understand the facts that have been discovered. In order that we may better understand this important phase of biology, we will now examine two interesting subjects, variation and heredity, and point out their relation to human progress.

405. Variation. — One of the surest ways to understand the scientific meaning of the term *variation* is to collect leaves from any tree. Maple or oak leaves are especially

satisfactory because of their irregular margins. When such a collection of oak leaves is available, try to find two that are identical in every detail. It will take but a few minutes to convince any one that the task is impossible. These differences which you have noted are known as *variation*. It is not correct to use this term *variation* to describe the differences that exist between maple and oak leaves, for example,

FIGURE 434. — VARIATION IN THE SIZE AND SHAPE OF TIMOTHY HEADS IN THE SAME KIND OF TIMOTHY.

(Photograph furnished by Cornell University.)

or the differences that exist between a cat and a dog. In the study of variation, we can only contrast differences in the same kind of animals or plants.

In Figure 434 is shown a photograph of the different sizes in the heads of timothy hay. The variations have to do with the length, thickness, and form of the head. In these heads are grown the seeds which are valuable as food to animals and they are used as seed when the farmer wishes to raise

a crop of hay. Figure 435 shows the practical value of planting seed that yields a large crop instead of a small one. In each of the five bundles in this figure, the same amount of seed was planted in the same kind of soil. Here we have a variation in the quantity of hay.

The amount of variation in living things is only partly appreciated, as complete studies have not been made. In a recent study of wheat a great deal of variation was noted, as is illustrated by Figure 436. Wheat is raised for the purpose of obtaining as large a yield as possible of wheat kernels.

FIGURE 435. — BUNDLES OF TIMOTHY RAISED UNDER IDENTICAL CONDITIONS FROM THE SAME AMOUNT OF SEED.

It pays to plant good seed. (Photograph furnished by Cornell University.)

A farmer who planted seed that produced plants with short and thin heads would harvest from ten to fifteen bushels per acre; while the one that planted seed that grew plants from which twenty-five to thirty-five bushels per acre could be had would be more successful.

In order to furnish the farmer with the necessary information upon all such subjects, scientific experts have been and are now devoting a great deal of time to experimentation. The following examples are given to show the importance of such studies in helping man to make plants grow as he wishes them to grow and thus control his environment.

The first example is a study of wheat. Figure 437 consists of bearded wheat, the pollen of which was placed on the stigma of the wheat flowers that formed on the non-bearded wheat shown at the right in figure. When the kernels of wheat in this head ripened, they were sown and a plant

FIGURE 436. — VARIATION OF THE SIZE AND SHAPE OF HEADS OF WHEAT. All grown from the same kind of wheat. (Photograph furnished by Cornell University.)

produced which grew a longer head with practically no beards (the middle head in Figure 437). Such a head of wheat would yield more kernels of wheat than either of the parent heads. Now if the scientific expert can make this new wheat plant permanent, that is, produce seed which will always grow large heads, he has furnished the farmer with a new kind of wheat and has made a new discovery.

FIGURE 437. — HEREDITY IN WHEAT.

The head of wheat on the left of this figure has beards. The pollen from the wheat flowers of this head was placed on the stigma of the wheat flowers that grew in the head shown in the right wheat head of this figure. When these kernels of wheat ripened, they were sown and produced a wheat plant that had more wheat kernels than either parent. This is the head shown in the middle. (Photograph furnished by Cornell University.)

What does the scientific man do who makes such a new discovery? He starts out to tell just as many people as he can that he has made a new discovery and asks them if they do not wish to try it. In order that as many people as possible shall have an opportunity to know about his new discovery, he writes a description of it and sends it to some scientific journal. He does not get any pay for his scientific article as do writers of stories, nor does he have his article copyrighted, but he invites any one who wishes to use his facts.

Another example has to do with variation in resistance to disease. The American grape is a North American plant

including from fifteen to twenty-five different species, about one half of the total number known to man. These different kinds of grapes grow in varied areas and climates. Their original distribution over North America was due to animals, such as birds, and to river currents.

The several varieties of American grapes are descendent from an original species which has become changed by environment until we find types of grapes as diverse as the regions in which they are found.

FIGURE 438. — LEAF GALLS ON GRAPE CAUSED BY GRAPE PHYLLOXERA.

The roots are also injured by this disease which threatened to destroy all of the European vineyards.

Many of these varieties have been in existence since white men came to this country. During this time they have acquired a strong resistance to certain parasitic diseases which are very destructive to the European grapes. Among them is one that is caused by a minute plant louse that lives either in the leaf, stem, or root. This insect is known as phylloxera (fĭl-ŏks-ē′ra) and is very destructive. In addition to this animal disease, there are three plant parasite diseases: black-rot, downy mildew, and powdery mildew. Each of these four diseases is able to kill grape plants and more than one may attack the same plant at the same time.

A few years ago these diseases became widespread in Europe and threatened to destroy most of the European vineyards. Many experiments were undertaken to save

this valuable industry and it was discovered that the European grapevine could be grafted on to the root of any one of several of the American grapes. When these vines were thus grafted, they were found to possess a resistance to these four diseases with the result that the vineyards of Europe were saved.

This success was due to scientific study which discovered the difference between the European and American grapes in regard to their power to resist disease and the fact that the quality of the European grape would not be altered by grafting it on the roots of the American varieties. Here we have an illustration of variation that is not confined to the shape and size of the parts but to their resistance to disease. This may be described as an acquired immunity that is transmitted by heredity from one generation of grapes to another. The word immunity used in this last sentence was explained on page 516. If we explain the scientific meaning of heredity, this brilliant discovery in regard to grapes will mean more to you.

406. Heredity. — An easy way to understand the technical meaning of this term which we use so frequently is to make a study of your hand. Normally we all have four fingers and one thumb but our hands are quite unlike. This is readily seen by comparing the three hands in Figure 439. The large one is the hand of father, the middle one of daughter, and the right one of mother. The first and the last fingers of the father's hand are about the same length, while the little finger of the mother is much shorter than her first finger. This difference in the length of these two fingers is repeated in the hand of the daughter. We say that the daughter inherited from her mother a short little finger and a long forefinger.

Now if we study the position of the thumb in its relation to the palm of the hand, it is seen that the distance between the thumb and the base of the forefinger is proportionately

greater in the hand of father than of mother. The same is true of the hand of daughter. When she grows to maturity, this distance will be much greater than it is in the hand of her mother. The daughter inherits this peculiarity in her hand from her father.

Make a study of the several parts of your own hand and compare your hand with the hand of your mother and father.

Figure 439. — Heredity Shown by Comparison.

Photograph of hand of father at the left, of mother on the right, and of daughter in the middle. Which parts of the daughter's hand are like her mother's? Which like her father's?

This study will show you what is meant by the term heredity as applied to your hand.

In a similar manner you can compare the color of your eyes and hair; length of arm; shape of head; muscular vigor; size of body; intellectual traits, such as interest in language, history, science, or business; and temperament, which includes liveliness, deliberateness, excitability, quickness, or slowness.

After you have made these comparisons, you realize that you are unlike both parents in that you have some features which are lacking in either your father or your mother. The total of the like parts and traits which are the same as in your father make up what you have inherited from your father; and the total of the parts and traits which are the same as those in your mother, make up what you have inherited from your mother. Thus we inherit from both parents.

But there are usually found some structures and characteristics that do not represent anything found in either parent. If such are carefully analyzed, it is usually discovered that they exist in some of the grandparents. It is always interesting to try to locate their origin.

This study of our hands and other parts of our body leads to an important general statement. *All the parts of our body with their individual peculiarities have existed in other human beings and these persons were your immediate ancestors* (parents, grandparents, great-grandparents, etc.).

This explanation of heredity applies to all animals and plants, so that we can study heredity in our war gardens or with our pet animals.

There is a limit to the differences that exist between child and parent, and these differences under normal conditions produce changes that would never make the structure a new one; for example, the finger is always a finger, and hair is always hair. Heredity is thus a descriptive, technical word used to explain the like parts between child and parent.

During the past fifteen years, there has been a great deal of experimental work upon plants and animals in an attempt to explain just how an offspring inherits from its parents. It is impossible to record these experiments here because they would make a book several times as large as this one. It is too soon to be entirely certain just what these studies mean. When we do understand, then we can explain heredity.

Sufficient progress has been made in the explanation of heredity so that those who raise prize horses, cattle, sheep, apples, berries, wheat, and other products can be reasonably certain that their efforts will be successful. The average American cow gives 3100 pounds (a pound is about one pint) of milk a year; while one cow has a record of giving 30,000 pounds in a single year. If the farmer can sell his milk for five cents a quart, the milk of the average cow would be worth $77.50 a year; while the prize cow would bring its owner $750. The variation in the amount of milk that a cow gives is an inherited character; so if the breeder selects animals that are big milkers, he can secure cows that will produce more milk than the breeder who does not make such a selection.

In a similar manner all well-informed men who deal with animals and plants seek to secure certain results, but they cannot produce a new kind of animal or plant. They simply magnify some of the parts and reduce others by a detailed study of the way these parts are inherited. Sometimes they spend years and are not successful and often the desired result does not remain fixed or permanent but disappears in the next generation. This is a phase of biology that you should try to keep in touch with for both its interest and value.

407. Relation of Variation and Heredity to Human Progress. — In a general way this has already been indicated, especially where the practical value in raising larger crops of hay or wheat or in producing more milk was mentioned. But we are also interested to learn how variation and heredity apply to man. Your study of your hands and the other parts of your body demonstrated to you that you had inherited certain peculiarities from your parents. As you studied these similarities, you found that there were small differences or variations. This is well illustrated in the study that is being made of finger prints. Each one of us has these minute

lines following a general pattern with an infinite number of variations possible. It is these very small variations that each one has that enable the expert to identify two finger prints made by the same person. The United States Government has selected finger prints as the surest way to identify its soldiers and many banks have long used the finger-print method of identification.

Is it possible to predict what human beings will inherit from their parents? In a very general way we can answer this question in the affirmative. One of the most striking ways in which this is seen is in a study of the inheritance of certain defects, such as feeblemindedness. This is a disease, the cause or causes of which are not well understood, but we do know that such people are usually unable to earn a living and have to be supported by public taxation. A large proportion of their children inherit this same mental defect. The scientific study of heredity has proved that this is the case and always will be so. It remains for us to decide what is the best thing to do with such people. What is true of imbecility is not true of most other diseases.

General ability and a tendency to industry and thrift are inherited by a large proportion of the children of the parents that possess these admirable traits. The men and women who possess such mental traits carry on the business of the country and pay taxes not only to support the government but also to care for the idle, the shiftless, and the criminal. If we have inherited these together with other valuable traits of character, we should take care that they are passed on to our children in order that the next generation shall possess enough men and women who will be able to advance human progress beyond our best efforts.

408. Environment. — All through this book attention has been directed to the environment in which the animal or plant lived that was being studied. The same fact was emphasized in the beginning of this section dealing with human

biology. When the environment of man is critically studied, it is noted that it may have a large influence upon him. Even though he may have inherited a strong body and a tendency to thrift and industry, he may find himself in a social environment that is so strong that he has great difficulty in earning enough money to keep alive. When the full influence of environment was appreciated, men and women began to insist that better housing conditions and a certain amount of fresh air and light must be provided in order that those who lived in the tenements should find it easier to keep well and thus be able to work. Even though their environment be not of the best, it is possible for them to become superior to it.

In the steady advance which human progress is making, the conditions under which men and women live and work are constantly growing better. As these conditions improve, there will naturally follow a larger opportunity for our inheritance to have its full influence upon us. Two noteworthy movements are already having a marked influence in this direction; namely, the prevention of the spread of biological diseases and the child welfare movement (see page 513). As we gain a clearer conception of the importance to man of variation and heredity, other movements will be undertaken to place man in greater control of his environment.

The fact that biology stimulates us to think about all such problems is one of the main reasons for studying it. But with all this scientific information at our disposal, much remains for the individual to do. He must realize his obligations and opportunities in the age in which he lives. A mere passive existence has never accomplished anything worth while. The desire to serve our country and our fellowman and a personal ambition must be added to our scientific information, if we would attain real success.

PART IV

GENERAL BIOLOGY — A REVIEW AND SUMMARY

409. Living Things. — We are ready now to make some comprehensive statements about animals and plants as we review the more important general facts. A few terms are employed to describe animals and plants, their structures and varied activities. Whenever you wish to make a general statement, such terms are indispensable. These terms are *organism*, *organ*, *tissue*, and *cell*. Associated with these four general terms is the word *adaptation*, which, like them, has a broad application. Explain why it is correct to apply the term *organism* to such different living things as the grasshopper, horse, man, paramecium, corn plant, pine tree, and yeast plant. Write definitions of the remaining terms that will indicate their general application to all living things.

Review the following: pages 1–4, 6–8; sections 30, 43, 89, 90, 97, 98, 183, 197, 200, 252; and figures 1–5, 95, 98.

410. Cellular Structure of Organisms. — We have seen that the root, stem, and leaf of the plant are made up of cells. Likewise the tissues found in animals are composed of cells. The human body with its organ systems, organs, and tissues is a grouping of cells. We find that all cells are much alike in structure and behavior, bringing these different and apparently unlike organisms still nearer together.

Review the following: sections 8, 10, 109, 251; and figures 4, 19, 47, 51, 65, 76, 197, 263.

411. Protoplasm. — The active living part of all cells is the protoplasm. This is the part that grows, moves, and makes the organism live. In a green plant that looks fresh

and strong, it is the protoplasm that gives it that appearance. When a kitten runs and jumps, it is the protoplasm of the cells that is active in reality. When a boy or girl skates or swims, we know that the good healthy protoplasm of the cells is at the bottom of such movements. So far as we can tell all protoplasm is much the same thing structurally and reacts in much the same way whether it is in the plant, kitten, or boy.

When a plant grows, it is adding more cells; when the kitten grows, it is adding more cells; and the man is the boy with more cells added and more training and adaptation acquired. Nowhere in the animal or plant kingdom can we get away from the fact that the foundation of all organic structure is the cell. As each brick is a unit in a great building, so each cell is a unit in the huge tree by the roadside, the elephant in the zoo, or the great man leading his army. We are as old as our cells and the condition of the cells tells the story of health. Healthy cells make healthy bodies.

Review the following: page 7; sections 6, 110; and figures 4, 76, 195, 198.

412. Principal Functions. — The principal functions of organisms are food-getting, digestion, assimilation, circulation, respiration, excretion, sensation, and reproduction. The food-getting methods of plants and animals vary widely. For the most part animals can move from a place of food shortage to another place where food is abundant. For the most part plants are anchored to a spot and must get their food there or starve. Animals take complex food substances and break them down into simpler substances; while plants take simple substances and build them up into more complex substances. This is the great difference between animals and plants as regards food-getting.

The world is richer in food values because of the plants, whereas the animals tend to undo the work of plants. This

is the reason why plants have always preceded animals, as they have come to live first in one place, then another. For the same reason the quantity of food substances made by plants must always exceed the demand made upon them by animals, else the animals will starve.

a. Food-getting in Plants. — Most plants get their food in the form of solutions through root-hairs and in the form of gases through the air. Root-hairs excrete substances that dissolve some otherwise insoluble materials and thus increase their food supply. Root-hairs are adapted to getting these solutions through their cell walls by osmosis. Leaves and young stems have stomata on their surfaces, which are openings that allow gases to pass through at certain times.

Review the following: sections 241, 268, 273, 278; and page 306.

b. Food-getting of Animals. — The simpler animals get their food in much the same way as root-hairs do, by simple osmosis. The higher animals have more elaborate structures for getting food. In the mammals, special organs, teeth, cut the food into smaller portions. It is then swallowed by muscles especially for that purpose and passed into the stomach.

Review the following: sections 3, 5, 44, 58, 81, 99, 150, 163, 174; and figures 3, 99, 106, 107.

c. Digestion. — The food in the stomach of a mammal is acted upon by an enzyme secreted by the living cells lining the stomach cavity. Different enzymes grown in the living cells of the pancreas and stomach produce further changes in the food after it reaches the intestinal cavity. The action of these different enzymes is to reduce the foods to solution, which is digestion. The parts of the food that are thus digested are made soluble and pass by osmosis into the blood. Food in the food-vacuole of the paramecium is digested in a similar manner. The stored-up starch and protein in the

leaf or stem of a plant must also be digested before it can be absorbed. Enzymes play an important part in shortening the time that it takes to change foods into solutions.

Review the following: pages 5, 13, 14, 15; sections 114, 120, 141, 206, 237, 246, 268, 326, 328; and figure 167.

d. Assimilation. — After food has been digested, it is absorbed. In the paramecium or yeast cell, it is taken at once into the living protoplasm. There are no special structures such as are found in all complex organisms. The food is distributed throughout the cell. This simple condition is not adequate when organisms are made up of thousands of cells and special methods of distributing the absorbed food are found.

e. Circulation. — The organs of circulation in higher organisms may well be compared to our transportation systems, the railroads. Their chief function is to carry food, oxygen, and bodily wastes from one part of the body to another. In animals this system is known as the heart, arteries, capillaries, and veins; and in plants, as the fibrovascular system of veins.

Review the following: sections 48, 110, 114, 120, 141, 233, 236, 237, 247, 248, 329, 357; and figures 64, 235, 256.

f. Respiration. — Oxygen furnishes a necessary amount of energy to all organisms. Animals that live on land have special organs, the lungs, that are adapted to taking oxygen from the air; while aquatic animals, like fish and crayfish, have gills that are adapted to take oxygen from the water. Some animals, like the earthworm or hydra, have the cells covering the body adapted for this work. Plants have their leaves modifed by stomata, and through these oxygen passes into the plants. Under some conditions, the stem takes up oxygen. Aquatic plants, like algæ, take up oxygen through the walls of the filament.

Review the following: pages 5, 10, 15; sections 6, 46, 59, 72, 115, 121, 142, 164, 175, 207, 237, 353; and figure 64.

g. Excretion. — The energy used by organisms in their several activities results in the formation of various wastes. These wastes are usually in the form of a gas, as carbon dioxide, given off in respiration by animals and plants, or as a liquid when discharged from the sweat glands and kidneys.

Review the following: page 5; sections 8, 47, 61, 73, 116, 122, 142, 165, 176, 237, 249, 358; and figure 73.

h. Sensation. — We do not know whether we have more than five senses, but no matter how many there may be, all require that special cells respond quickly to various stimuli, such as light, heat, sound, etc. Such cells help man to understand his environment, and the more he trains his sense organs, the greater will be his capacity to enjoy nature. If our sense organ cells were not connected with the brain by nerves, they would be of but little use to us. Man has the most highly specialized brain of any animal.

Most animals have sense organs and some form of a nervous system. The presence of such organs indicates a form of division of labor. But there are animals without sense organs or a definite nervous system. Such animals rely upon the general sensitiveness of the protoplasm to make them aware of changes in their environment. Plants do not have sense organs or a nervous system, yet they respond to light and dark, summer and winter.

Review the following: page 6; sections 6, 49, 62, 74, 77, 110, 123, 143, 177, 363; and figure 74.

i. Reproduction. — The unicellular plants and animals reproduce in a very simple manner by fission. In multicellular organisms reproduction begins in a single cell, the germ cell. This germ cell has the power to carry on a program of development that varies but little for all eggs of one kind. The fish egg and the frog egg look much alike, but each follows its own individual order in development until the adult stage is reached. There is no mistake, and the development is never interrupted, and there can be no pause

without disaster to the life of the forming organism. An egg may be kept before starting to hatch; but once started, it must continue. There is considerable variation in the exact manner in which the eggs of different animals develop. Some have a very large amount of food stored in the egg, as hens' eggs, which influences the manner of embryonic growth.

Review the following: page 6; sections 10, 50, 63, 67, 75, 84, 92, 117, 124, 134, 144, 145, 167, 178, 275, 281, 286; page 305; and figures 66–67, 75–80, 180, 191, 193.

413. Interdependence of Animals and Plants.—As we have seen, plant life must precede animal life. Plants can take water, carbonic acid, and a few minerals, and make starch, sugar, proteid, etc. Before there were any animals on the earth, the plants were thriving and building foods. These foods with no animals to eat them decayed and made up rich soils for further plant growth. This continued till the animals appeared on the earth.

These animals ate some of the foods that the plants made and in time died and their bodies together with the dead plants went back to the soil and made it still richer and able to produce better and more nourishing foods. This process has been going on for ages, and the plants have been furnishing the food for the animals' bodies. At death the animal body goes back into the soil, making it richer in plant food and able to produce more plants and better food crops. Thus the plants are helped by the decaying animal bodies, and the animals themselves must have the plants for food during their life time.

Of course, some animals eat flesh, but eventually in tracing back we come to the animal that feeds upon the plant food. The house cat, for example, eats mice, but the mice eat grains, and so we find the cat, a flesh-eating animal, dependent on animals that must have plant food.

Review the following: sections 1, 15, 21, 28, 185, 245, 311, 314.

414. Relation of Animals and Plants to Man. — No summary of a general course in biology would be complete that did not indicate some of the general relations of living organisms to man. They are our indispensable friends or unceasing enemies. The story of how man has come to control the multitudes of living things is as full of interest as it is important to the continuance of a progressive civilization. There still remains much for man to discover, but we should be intelligent about what has already been accomplished.

Man makes a greater use of the plant world than any other animal, and he uses the animal world for his benefit far more than any other animal. Because man is the highest type of animal he has gained mastery over plants and animals. Those nations that have found out the best ways to utilize the greatest number of plant and animal products are the dominating powers of the world. Closely associated with man's utilization of the organic world is his greatly improved use of natural forces and of the inorganic world.

Review the following: sections 16, 66, 107, 136, 148, 158, 160, 169, 182, 195, 208, 257, 263, 269, 270, 282, 289, 294, 295, 296, 299, 300, 310, 315, 330, 333; page 296; chapters II, XXXV, XXXVI.

415. Community Life. — It has often been said that man is a social animal. Man is not the only social animal. The communal life of the honey-bee, ants, and termites shows many wonderful examples of labor for the benefit of a whole colony. The honey-bee, when first out of the cocoon, as an adult is a nurse for the larvæ, later a wax-maker for the colony, and later a field worker, a gatherer and maker of honey. Most of the work of the midsummer honey-bees is for others, since they die before winter begins. Consequently these bees are community builders in a real sense of the word. Those insects that have the greatest number of workers and the most extensive division of labor are the most successful in the struggle for existence. When we

find the lower animals, especially insects, succeeding in their struggle for existence because of their community life, we do well to apply some of the lessons of the honey-bee to our life as members of a community. Honey-bees are instinctively sanitary. When an insect too large to move is killed in their hive, they embalm it. This tends to make the hive sanitary. Man in building sewage disposal plants and sewer systems is improving the health of the community. It is for the best interests of the majority that such care be taken with regard to public health.

Honey-bees remove all waste pieces of rubbish, dirt, and loose pieces of every description from their hives. If a larva dies in the comb, the bees remove it and scrape and polish the wax directly. Honey-bees have epidemics such as "foul brood." The bees that clean their hives most and work the hardest to keep clean are quickest to recover.

Human animals are subject to epidemics, and those that work the hardest to keep clean and use care recover most quickly. Man has learned that many diseases are contagious, and quarantines are maintained to prevent their spread.

Bees never enter the hive of another colony unless to rob it of honey. But foul brood often kills or weakens an entire colony and the robber bees who enter and steal the honey carry home also the disease and thus it spreads. If the honey-bees maintained their usual habit of not going into other colonies, the disease would spread with difficulty.

Bees act from instinct, and man is endowed with reason in addition to his instinct, and, naturally, we find man at his best carrying on a much broader line of community activities; for example, setting aside large tracts for public parks, in order that all people may go and enjoy the growing plants and see the animal life in its varying aspects.

Man is improved mentally and spiritually by getting away from the daily routine of a business or professional life and

coming in contact with the great world of nature. So we find that as man is compelled to live in cities, where highly specialized conditions deprive him of the pleasures of the natural world, he is constantly adding to the parks and "breathing places" where he may go and "commune" with nature.

Everywhere we see this tendency of man's nature to get into contact with the real, natural world. House plants, birds in cages, bird-nesting boxes in the yard, trees by the roadside and flower gardens at the door — all these are results of man's efforts to commune with nature.

Review the following: section 29; and figures 33, 37.

416. Conservation. — As man has utilized some of the plants and animals for his advancement he has, in many cases, so wantonly handled them that there is danger of the supply being exhausted. In his haste for lumber to build houses and barns, he is selfishly cutting down trees in great quantity and leaving not sufficient to grow for the next generation. In his anxiety to get a big catch of fish, he has been catching so many as to leave none to lay the eggs for a new generation. Almost before we were aware of the damage that was being done, some animals and plants had been exterminated.

Now we are looking ahead to see where the future lumber is going to grow; as a result we have forestry schools. Now we are thinking of the wild life that is growing less in numbers and variety, and we are passing laws to protect it. Some one has said that we are merely guardians of the wild life, and that we must account for our stewardship to the generations that come after. It would not do to pass on to future generations an earth depleted and robbed of wild life and made up of barren hills and rain-washed slopes.

So we are interesting ourselves in this big question of conservation, which is really acting as stewards of the earth for the benefit of the people who are to follow us. Every

one can plant trees, make gardens, and protect and feed the birds; and so every one may be a conservationist.

Review the following: sections 66, 95, 96, 97, 100, 101, 317, 318, 319, 322, 323.

417. Public Health. — While we are conserving wild life and planning that the next generation may have a world rich in objects of natural beauty, there is danger that we may forget our own health. We owe it to the world to keep in good health. When we are ill we are not preparing for work, and we are not producing anything of value. We are taking the time of physicians, nurses, and friends, and preventing them from doing other work that would make the world a better place to live in.

When we are ill it is generally because some one has been careless. It may not be our own carelessness, but generally some one is at fault. For violating nature's laws we generally pay the price — sometimes at once, sometimes later. It is our business to know these laws and then to obey them. We are coming to think of public health as something that may be bought. For example, water supplies may be protected and purified, if we install the proper equipment. This costs money, but pure water will make a community healthier, and it is worth money to a community to have all its people well, for they can work and add to the value of property.

Certain diseases may be prevented if vaccines and antitoxins are prepared and used at the proper time. The making of these vaccines costs money, but they may be purchased. So we are right when we say that public health is purchasable, provided we know what to purchase and how to use what we purchase intelligently. So we find various states with departments of health that are trying to improve the health of the people and lower the death rate. It really pays the state in money if it can lower the death rate.

The United States has its department of health that tries to prevent diseases from other countries from entering our land through ports and harbors. More and more the discoveries of medical men and biologists are making people healthier, and it is our duty to acquaint ourselves with the new discoveries bearing upon matters of health.

Review the following: sections 29, 35, 160, 182; and figures 45–47.

418. Departments of Agriculture and Forestry. — Aside from the health work of the states and the national government we find them active in many other fields. Among their other important functions is that which deals with crops and their enemies, new ways of treating the soil, control of seed testing, analysis of various fertilizers, and many other kinds of work that have to do with farming and forestry.

There are so many other uses of forests than simply furnishing lumber that certain forests are not used for lumber at all. The regular flow of some rivers and spring streams is due to the permanence of the forests on their watershed. Take away the forests entirely and many springs would not furnish water in dry seasons, many streams would dry up, and fish would die.

The forests are important directly and indirectly to many people. Recently the people of the State of New York voted to buy thousands of acres in the Adirondacks in order that all the people might have some of the benefits that come from forests. The reclaiming of arid lands and making them productive in the Western States is another government activity that has to do with agriculture and the increased production of food crops.

Review the following: section 182; and chapters XXVII, XXIX.

419. Plant and Animal Improvement. — We are accustomed now and then to hear discussions that give an idea

that the things of years ago were as good as those of our day, or better. Some say the apples of years ago were better or kept better or yielded better than the ones we raise to-day. As a matter of fact, apples, peaches, oranges, wheat, corn, and all the products of the soil to which man has given serious attention are bigger, better, and yield more than ever before. By careful selection of seed, larger yields of superior crops are easily attainable. The state and national governments maintain experimental stations where work of this nature is carried on. Much other valuable work in the way of insect control and soil study is done at these stations.

420. Natural and Artificial Selection. — In nature there is a constant struggle among all living things for place, food, and opportunity. Whatever aids a plant to grow and shade another plant will give the winning plant an advantage. Whatever gives an animal protection from its enemies will enable that animal to survive. Some do not find protection and thus perish. Nature selects those forms of life that are best fitted to meet all the natural requirements of the world where they live.

Man steps in and selects animals for other reasons than those before mentioned. Man may want a fruit of a certain flavor, or flowers of a certain color, or milk containing a certain amount of butter-fat, or corn with a certain number of rows of grain on a cob, and he selects the seed that will help him do this, or he selects the cows that will give milk rich in butter-fat, and eventually he may find what he wants.

Whatever selection man may make is artificial selection, while the selection that is made in the world outside of man's control is natural selection. It is natural selection that has done the most to make the great variety of plants and animals in the world, and it is competition, with the elimination of the weak and unfit, that makes for the improvement of

the races of plants and animals. A world without competition would degenerate and would be impossible in the condition that we know it.

Review the following: sections 80, 103, 104, 105, 106, 208, 320, 321; and page 270.

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